Photo Emission

OP1020

OPS

MP MASTER

MA30231

OP1020

SURFACE

QUALITY MONITOR

OPERATING MANUAL

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Version OP1020.391

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For any assistance, contact your nearest Photo Acoustic representative.

TABLE OF CONTENTS

SECTION		PAGE
I.	GENERAL INFORMATION	
	1.1 Introduction	1
	1.2 Description	1
	1.3 Specifications	1
	1.4 Equipment Supplied	1
	1.5 Optional Equipment Available	2
II.	INSTALLATION	
	2.1 Introduction	3
	2.2 Initial Inspection	3
	2.3 Power Requirements	3
	2.4 Installation	4
	2.5 Repackaging for Shipment	4
III.	OPERATING INSTRUCTIONS	
	3.1 Introduction	5
	3.2 Description	5
	3.3 Controls and Indicators	5
	3.3.1 Control Unit	5
	3.3.2 Front Panel	5
	3.3.3 Rear Panel	7
	3.3.4 Rear Panel Connector Information	9
	3.4 Sensor	11
	3.4.1 Sensor Controls/Indicators	11
	3.5 Sensor Options	13
	3.6 Turn On Procedure	18
	3.7 Testing Instructions	18
	3.7.1 Control Unit Test	18
	3.7.2 Peak Detector Test	20
	3.7.3 Sensor Test	20

SECTION		PAGE
3.8	Operating Modes	21
3.8.1	Peak Detect Mode	21
3.8.2	Scan Mode	21
IV.	ADJUSTMENTS MAINTENANCE AND TROUBLESHOOTING	
4.1	Introduction	23
4.2	Adjustments	23
4.2.1	General	23
4.2.2	Equipment Required	23
4.2.3	Irradiance Measurement	24
4.2.4	Current Adjustment	24
4.3	Maintenance	25
4.4	Troubleshooting	26

LIST OF TABLES

TABLE		PAGE
1.1	Model OPO1020 Specifications	1
1.2	Equipment Supplied	2
1.3	Accessory Equipment Available	2
2.1	Fuse Requirements	3
3.1	Sample Ground Connector	9
3.2A	Output 9-Pin Female 'D' Connector	10
3.2B	Output 25-Pin Female 'D' Connector	10
3.3	Analog Output - BNC Receptacle	11
3.4	Sensor Multi-Pin Receptacle	11
3.5	Sensor Amplifier Gain Range	13

LIST OF ILLUSTRATIONS

FIGURE		PAGE
3.1	Front Panel	6
3.2	Rear Panel	8
3.3	Rotary Gain Switch, Close-Up View	12
3.4	OPX110 - Round Area Sensor	14
3.5	OPX200 - Rectangular Sensor (6" x 1/4")	15
3.6	OPX210 - Rectangular Sensor (2" x 1/4")	16
3.7	OPX310 - Single Disk Sensor	17
3.8	60004 - Aperture Set for use with OPX110	19

APPENDIX: AN OVERVIEW OF OSEE

SECTION			PAGE
1.0	INTRODUCTION		1
2.0	OSEE PRINCIPLE		1
	2.1	Resolution	3
	2.2	Repeatability & Reproducability	3
	2.3	Calibration	6
	2.4	Factors Effecting OSEE	7
		2.4.1 Short-term Factors	7
		2.4.2 Long-term Factors	15
3.0	PHOTO EMITTING MATERIALS		16
	3.1	Substrate Emitting and Contaminant/Coating Non-Emitting	17
	3.2	Substrate Non-Emitting and Contaminant/Coating Emitting	17
	3.3	Substrate and Contaminant/Coating Emitting	17
	3.4	Substrate and Contaminant/Coating Non-Emitting	17
4.0	APPLICATIONS OF OSEE		21
	4.1	Surface Cleanliness Monitoring	21
		4.1.1 Establishing Surface Cleanliness Level	22
		4.1.2 Sample Applications	23
	4.2	Detecting Absence/Presence of Films/Coatings	24
		4.2.1 Establishing Acceptance Criteria	24
		4.2.2 Sample Applications	25
	4.3	Measuring Thickness of Thin Films/Coatings	25
		4.3.1 Establishing OSEE Versus Thickness Relationship	26
		4.3.2 Sample Applications	27

SAFETY INSTRUCTIONS

The following general safety precautions must be observed during all phases of operation, service, and repair of this instrument. Failure to comply with these precautions or with specific warnings elsewhere in this manual violates safety standards of design, manufacture, and intended use of the instrument. Photo Acoustic Technology, Inc. assumes no liability for the customer's failure to comply with these requirements.

GROUND THE INSTRUMENT

To minimize shock hazard, the instrument chassis and cabinet must be connected to an electrical ground. The instrument is equipped with a three-conductor AC power cable. The power cable must either be plugged into an approved three-contact electrical outlet or used with a three-contact to two-contact adapter with the grounding wire (green) firmly connected to an electrical ground (safety ground) at the power outlet.

DO NOT OPERATE IN AN EXPLOSIVE ENVIRONMENT

Do not operate the instrument in the presence of flammable gases or fumes.

KEEP AWAY FROM LIVE CIRCUITS

Operating personnel must not remove instrument covers. Component replacement and internal adjustments must be made by qualified maintenance personnel. Do not replace components with power cable connected. Under certain conditions, dangerous voltages may exist even with the power cable removed. To avoid injuries, always disconnect power and discharge circuits before touching them.

DO NOT SERVICE OR ADJUST ALONE

Do not attempt internal service or adjustment unless another person, capable of rendering first aid and resuscitation, is present.

DO NOT SUBSTITUTE PARTS OR MODIFY INSTRUMENT

Because of the danger of introducing additional hazards, do not install substitute parts or perform any unauthorized modification to the instrument. Return the instrument to Photo Acoustic for any service and repair to ensure that safety features are maintained.

WARNING

1. The ultraviolet (UV) lamp in the sensor operates at high voltage (starting voltage is approximately 800 VAC, and the lamp operates at approximately 270 VAC). ALWAYS turn the Control Unit power OFF before connecting or disconnecting a sensor at the rear panel connection. Failure to do so may damage the system's electronic circuitry.

2. Inspect the sensor cable and plug before each use for possible wear. If the cable jacket is damaged or worn to the extent that the inner wires are exposed, the cable must be repaired before using the sensor. Make sure that the strain relief collet in the plug is holding the cable securely. If the cable can be rotated or moved in and out of the plug, the assembly must be repaired before using the sensor. Repairs should only be performed by trained personnel.

3. *AVOID LOOKING* directly at the UV lamp in the sensor. The sensor emits UV radiation which can be harmful to the eyes and skin. For protection, wear UV protective glasses and avoid direct exposure to skin.

4. The UV lamp in the sensor generates ozone due to the interaction of UV radiation and oxygen in the air. The operator must ensure that adequate ventilation exists to prevent excessive ozone build-up. (Note that ozone concentrations as low as 0.1 ppm can cause headaches.)

SECTION I: GENERAL INFORMATION

1.1 INTRODUCTION

This section contains general information about the Model OP1020 Surface Quality Monitor. Included are: description of instrument, equipment specifications, equipment supplied and accessory equipment available.

1.2 DESCRIPTION OF INSTRUMENT

The Model OP1020 Surface Quality Monitor measures Optically Stimulated Electron Emission (OSEE) from a surface which is exposed to ultraviolet (UV) light by the sensor. The measured signal can be displayed on the Digital Panel Meter (Fig. 3.1, Ref. 2) and is also available as an analog output (Fig. 3.2, Ref. 5).

The OP1020 has adjustable gates to sense the level of the sensor signal and provides logic information to on board visual indicators as well as to associated process control equipment.

1.3 EQUIPMENT SPECIFICATIONS

TABLE 1.1 - MODEL OP1020 SPECIFICATIONS

Number of channels	1
Output Indicator	Red and Green lamps; DPM
Output,other	0 to 12 VDC
Sensitivity Gain Range	1 to 500,000 Normalized Gain
Area Inspected	Variable- 0.2mm to large area scan (depending on sensor size & number)
No. of sensors	1 standard (additional sensors optional)
Operating Voltage	110V,50/60Hz;220V,50/60Hz optional
Console Size	7"H x 12.75"W x 18.75"L ; 35 lbs.
Sensor Connector Cable	6 feet (up to 100 ft. optional)
Temperature Range	20 to 40 C°
Resolution	10% of area inspected
'Thin Layer' Detect range	1 to 2000 A approx. (depending primarily on material)

1.4 EQUIPMENT SUPPLIED

The equipment supplied with each Model OP1020 is listed and described in Table 1.2 below:

TABLE 1.2 - EQUIPMENT SUPPLIED

IDENTIFICATION NUMBER	QUANTITY	DESCRIPTION
OP1020	1	Control Unit
OPX110	1	Round Area Sensor
17251	1	Power Cord
1581-60	1	Ground Cable
OM1020	1	Operating Manual

1.5 OPTIONAL EQUIPMENT AVAILABLE

TABLE 1.3 ACCESSORY EQUIPMENT AVAILABLE

IDENTIFICATION NUMBER	DESCRIPTION
OPX200	Rectangular Sensor (6"x1/4" or 15.2cm x 6.4cm opening)
OPX210	Rectangular Sensor (2"x1/4" or 5.1cm x 6.4cm opening)
OPX310	Disk Inspection Sensor; Single Sided (3/4" x 1/4" opening)
OPX320	Disk Inspection Sensor; Double Sided (Both sensors 3/4" x 1/4" opening)
60019 with OPX110	Set of six (6) Apertures to enable (For use inspection of smaller areas.

SECTION II: INSTALLATION

2.1 INTRODUCTION

This section contains information and instructions necessary for installation and shipping of the Model OP1020 Surface Quality Monitor. Included are initial inspection procedures, power requirements, installation information, and instructions on repackaging for shipment.

2.2 INITIAL INSPECTION

The Model OP1020 Surface Quality Monitor is given a careful mechanical and electrical inspection before shipment. As soon as the Model OP1020 is received, verify that the contents are intact and as ordered. Although the instrument should be free of mars and scratches and in perfect electrical condition, it should be inspected for any physical damage which may have occurred in transit. Also test the electrical performance of the instrument using the procedures given in paragraph 3.7. If any physical damage or electrical deficiency is found refer to the warranty in this manual. Should shipping of the instrument become necessary, refer to paragraph 2.5 for repackaging and shipping instructions.

2.3 POWER REQUIREMENTS

2.3.1 The Model OP1020 can be operated from any 115V 50/60 Hz source and can be supplied, as an option, to operate on 220V, 50/60 Hz. The AC line fuse is dependent on the operating voltage. The fuse size can be determined from the following table.

TABLE 2.1 - FUSE REQUIREMENTS

Operating Voltage (Volts)	Fuse Rating (Ampere)
110	1.50
220	0.75

2.3.2 The Model OP1020 is equipped with a three-pronged power cord. To protect operating personnel it is necessary to preserve the grounding feature of this plug when using a two contact AC outlet. Use a three-prong to two-prong adapter and connect the green pigtail lead on the adapter to ground.

2.4 INSTALLATION

The Model OP1020 is a unit suitable for bench top use. The sensor should be plugged into the socket on the rear panel (Fig. 3.2, Ref.7). The ground cable should be plugged into the rear panel (Fig. 3.2, Ref. 3) and the other end of the ground cable should be connected to the sample or to the surface (preferably conductive) that is in contact with the sample. The power cord should be plugged into the rear panel (Fig. 3.2, Ref. 6) and connected to an AC outlet.

2.5 REPACKAGING FOR SHIPMENT

The following paragraphs contain a general guide on repackaging for shipment. If you have any questions, contact your local Photo Acoustic representative.

NOTE: If the instrument is to be shipped to PHOTO ACOUSTIC TECHNOLOGY for service or repair, attach a tag to the instrument identifying the owner and indicate the service or repair to be accomplished. In any correspondence, identify the instrument by model number and serial number.

For packaging, proceed as follows;

a) Wrap the instrument in plastic, preferably bubble pack, before placing in an inner container.

b) Use packing material around all sides of instrument, protect front panel face and handles with foam strips or bubble pack strips.

c) Place instrument and inner container in a heavy carton and seal with strong tape.

d) Mark shipping container with "DELICATE INSTRUMENT", "FRAGILE", etc.

SECTION III: OPERATING INSTRUCTIONS

3.1 INTRODUCTION

This section contains identification of system controls and indicators, turn-on procedures, test procedures, and operating instructions for the Model OP1020 Surface Quality Monitor.

3.2 DESCRIPTION

The OP1020 Series Surface Quality Monitor is a system that measures Optically Stimulated Electron Emission (OSEE) from surfaces (for more information on OSEE, see Appendix A). The system provides controls for accepting or rejecting the surface based on established standards for surface contamination or thin layer thickness. The system consists of a control unit and one surface inspection sensor.

3.3 CONTROLS AND INDICATORS

Each operating control, indicator and connector located on the Model OP1020 is identified in Fig. 3.1 and 3.2. The following paragraphs describe each of these components.

3.3.1 *CONTROL UNIT* - The control unit houses the UV lamp power supply, a DC power supply and the electronic circuit boards.

3.3.2 *FRONT PANEL (Figure 3.1)*

SAMPLE GROUND WARNING INDICATOR (Ref. 1)

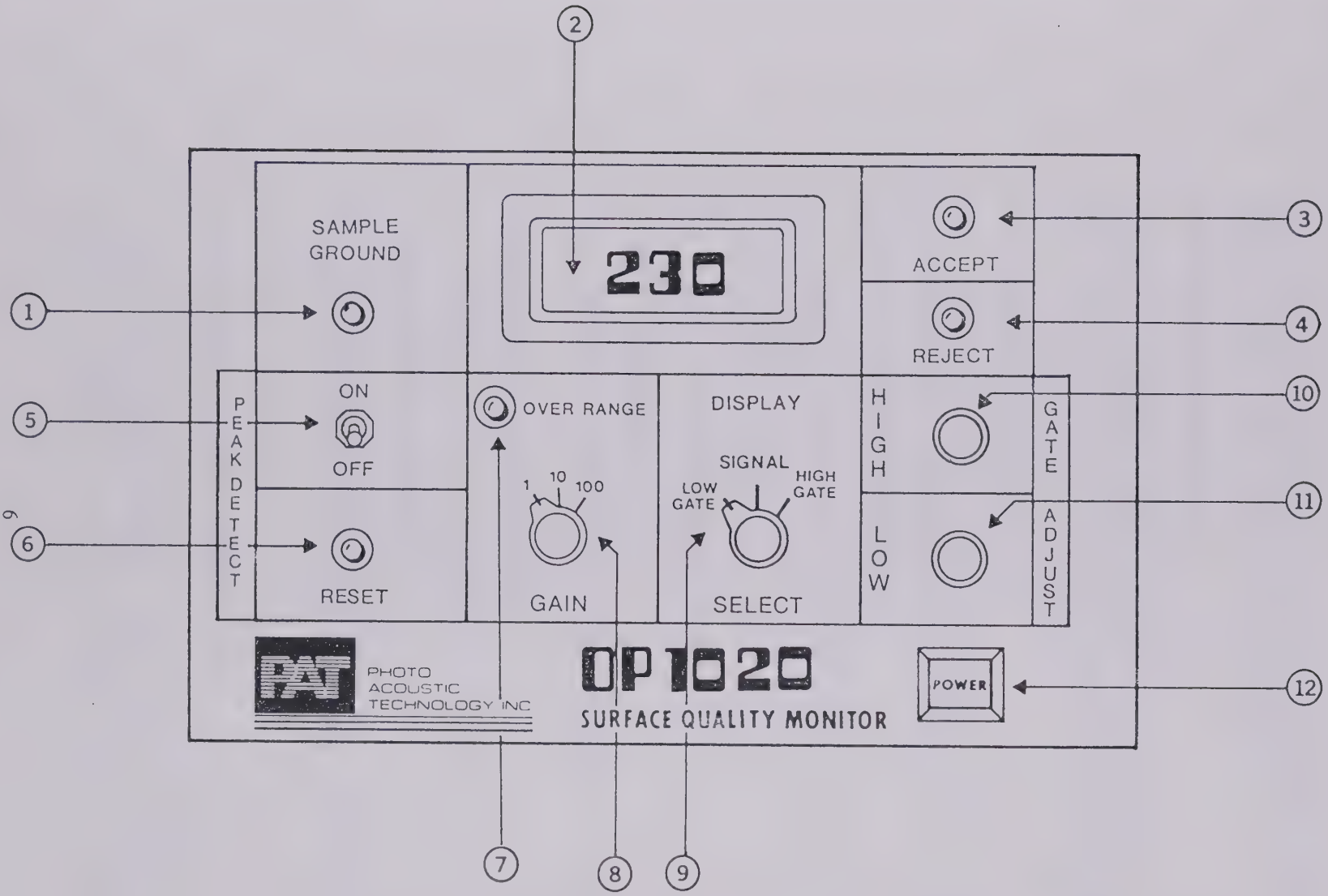
This indicator will flash if the surface to be inspected is not properly connected to the Sample Ground (Fig. 3.2 Ref. 1) on the rear panel. A proper connection will turn the indicator off. It must be emphasized that best results from the system will be obtained only if the surface to be inspected (metallic or non-metallic) is "grounded" using this method. This provides a return path for current and also reduces static charges.

DIGITAL PANEL METER [DPM] (Ref. 2)

The DPM can be selected to display (in relative numbers) the sensor signal, the high gate setting or the low gate setting.

SURFACE CONDITION INDICATORS (Ref. 3 and 4)

These lamps indicate whether the sensor signal is "in" or "out" of the



OP1020 — FRONT PANEL

FIGURE 3.1

gate settings. The green Accept lamp (Ref. 3) will light when the sensor signal is within the gate settings. The red Reject lamp (Ref. 4) will light when the sensor signal is outside of the gate settings.

PEAK DETECT ON/OFF (Ref. 5)

Placing this switch in the ON position activates the peak detector. The DPM will then display and hold the maximum value of the applied signal. In the OFF position the peak detector is disabled. (The peak reading held by the DPM will slowly decrease because of capacitor "leakage").

PEAK DETECT RESET (Ref. 6)

This push button clears the present value displayed on the DPM (see Peak Detect ON/OFF) and resets the peak detector for the next reading.

OVER RANGE INDICATOR (Ref. 7)

This indicator will light if the Gain Control (Ref. 8) is set too high for the sensor signal.

GAIN CONTROL (Ref. 8)

This control adjusts the gain of the control unit.

DISPLAY SELECT (Ref. 9)

This control selects the signal which is to be displayed on the DPM (Ref. 2).

HIGH/LOW GATE ADJUST (Ref. 10, 11)

These controls are used to adjust the High and Low gate settings.

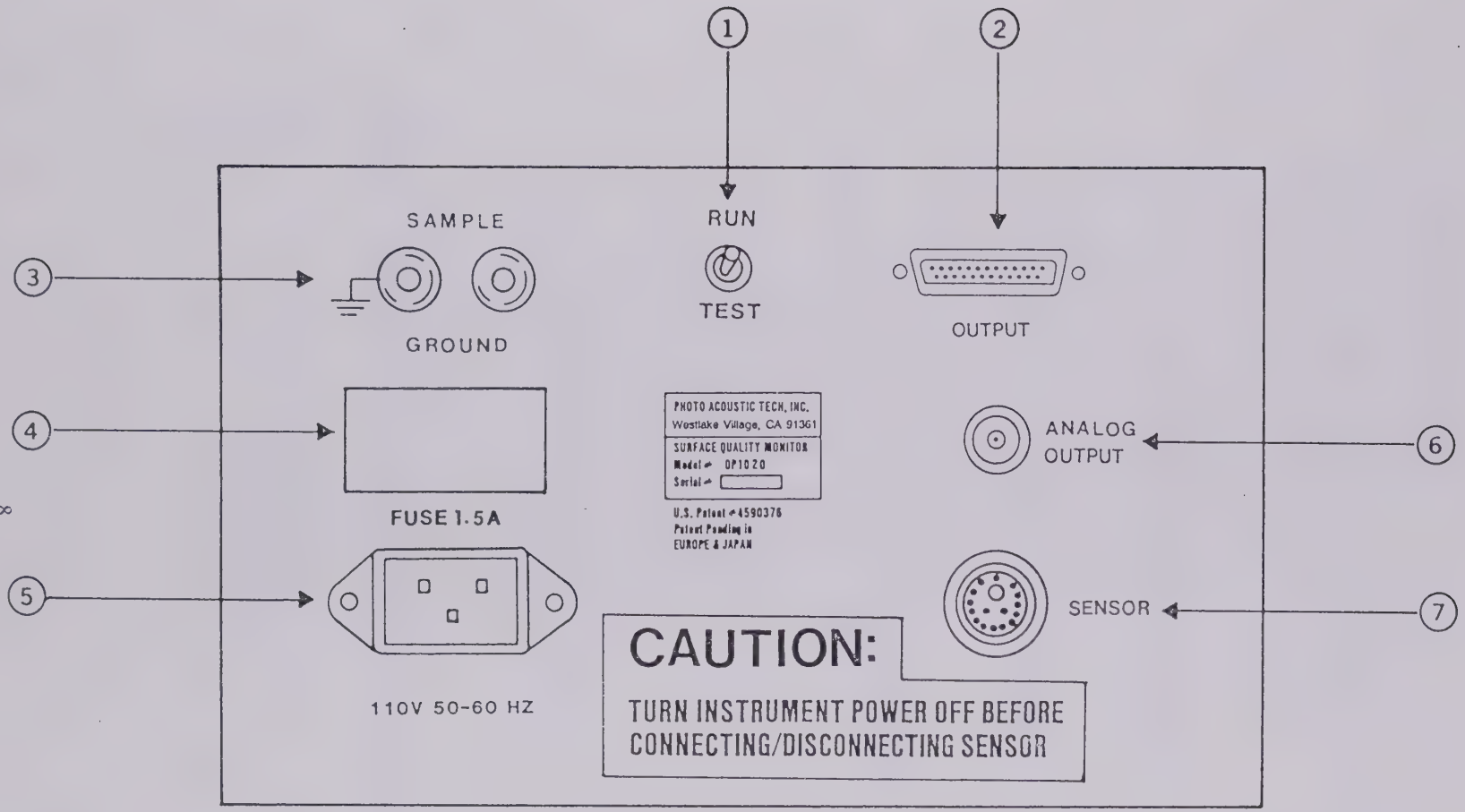
AC POWER SWITCH (Ref. 12)

This push button switch controls the AC power line. A built in lamp is illuminated when power is applied to the instrument.

3.3.3 REAR PANEL (Fig. 3.2)

SAMPLE GROUND CONNECTOR (Ref. 1)

For "grounding" of the surface to be tested. Use the grounding cable supplied with the instrument and connect both alligator clips to the sample or sample fixture. If the alligator clips are not effectively connected the sample ground warning indicator on the front panel will flash.



OP1020 — REAR PANEL

FIGURE 3.2

RUN/TEST SWITCH (Ref. 2)

This switch places the instrument in either the Run (normal operation) mode, or a Self-Test mode. The Self-Test mode allows for testing of the display, the output circuitry, the high and low gate controls and the associated visual indicators. The sensor is not tested.

OUTPUT CONNECTOR (Ref. 3)

Provides for output of the sensor signal and the gate status. (For Pin Out and current limitations see Table 3.2 on Page ?.)

FUSE (Ref. 4)

Circuit protection: Use 3AG "normal-blo" fuse of ampere rating as given in Table 2.1.

ANALOG OUTPUT (Ref. 5)

For output to a recorder, etc., of the sensor signal. (Note current limitations, etc. in the description for this connector, Table 3.3, page ??).

POWER LINE CONNECTOR/EMI FILTER (Ref. 6)

For connecting the instrument to the AC power line.

SENSOR CONNECTOR (Ref. 7)

For attaching the sensor to the instrument. NOTE: DO NOT connect or disconnect the sensor while the AC power is ON. Failure to observe this precaution may cause damage to the instrument.

3.3.4 REAR PANEL CONNECTOR INFORMATION

TABLE 3.1: SAMPLE GROUND (FIG. 3.2, REF. 1) DOUBLE "BANANA JACK"

PIN	DESCRIPTION
Left	Common (ground)
Right	To Sample Ground warning lamp logic

TABLE 3.2A: OUTPUT (FIG. 3.2, REF. 3) 9 PIN FEMALE "D" CONNECTOR

PIN	DESCRIPTION
1	+5 VDC , 25 ma max.
2	Not used
3	Do not use (Connected internally to sample ground)
4*	"Gate", Open Collector, Low = Signal is "outside" of gate settings
5	Signal out
6	Common (Ground)
7	Not used
8*	"Gate", Open Collector, Low = Signal is "outside" of gate settings
9	"Gate", TTL logic, Low = Signal is "outside" of gate settings

* Note: Pins 4 and 8, Open Collector outputs, can sink 25ma.

TABLE 3.2B OUTPUT (Fig. 3.2, Ref. 3) 25 Pin Female "D" CONNECTOR

For 9 Pin Female "D" Connector - See Table 3.2A

Pin #	Function
1	+5 vdc
2	not used
3	sample ground (connecting to pin # 14 turns "off" sample ground warning lamp)
4	"out" of window (low if signal is "out" of window)
5	Analog signal
6	not used
7	not used
8	not used
9	not used
10	not used
11	not used
12	not used
13	not used
14	ground
15	not used
16	"out" of window (same as pin #4)
17	"out" of window (same as pin #4)
18	run/test (connecting to pin 1 activates test" mode)
19	not used
20	not used
21	not used
22	not used
23	not used
24	not used
25	not used

NOTE: Pin 2, 4, & 16 are open collector outputs, Pin 17 is TTL.

TABLE 3.3: ANALOG OUTPUT (FIG. 3.2, REF. 5) BNC RECEPTACLE

DESCRIPTION

Analog Output , 0 to 13 VDC, @ 2 ma max.

NOTE: The "low" side of the BNC connector is internally connected to common (ground).

TABLE 3.4: SENSOR MULTI-PIN RECEPTACLE (FIG. 3.2 - REF. 7)

Pin	DESCRIPTION
1	Red lamp
2	U.V. lamp control
3	U.V. lamp feedback
4	Cable "shield"
5	U.V. lamp safety
6	U.V. lamp "neutral" (connected to Common)
7	+ 15 VDC
8	- 15 VDC
9	Common (ground)
10	Not used
11	Not used
12	Not used
13	Not used
14	"Active"
15	Signal
16	Green lamp
17	Not used
18	Not used
19	U.V. lamp "supply" (CAUTION! - up to 1600 VAC)

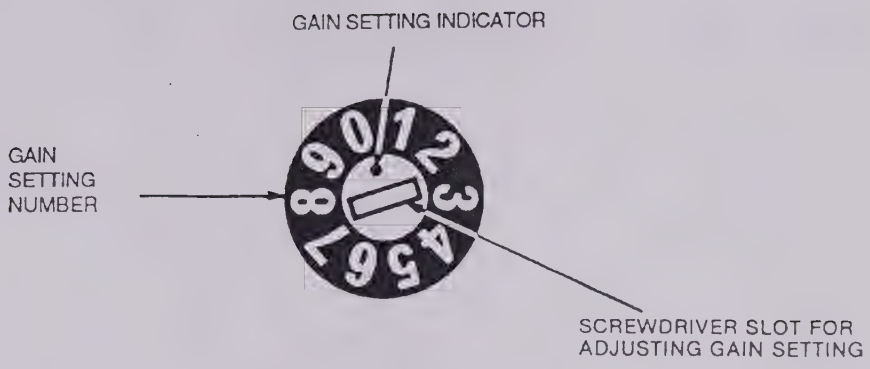
3.4 SENSOR (FIGURE 3.3 - 3.8)

The sensor contains an ultraviolet (UV) lamp, a detector, detector biasing circuitry, and amplification electronics. Round Area Sensor and other versions of the sensor are available as standard items. Custom designed sensors can be manufactured to customer specifications. (Consult factory for details.)

3.4.1 SENSOR CONTROLS/INDICATORS

GAIN CONTROL SWITCH (Fig. 3.3)

This rotary gain switch is used to adjust the gain setting of the signal amplifier. The lowest gain setting is 1 and the highest gain setting is 0. The gain setting



ROTARY GAIN SWITCH - CLOSEUP VIEW

FIGURE 3.3

is indicated by the number (on the outer ring of the rotary switch) opposite the dot (on the inner ring of the rotary switch). See Fig. 3.3 on page 14.

The following Table 3.5 defines the relative gain factor of each gain setting.

TABLE 3.5: SENSOR AMPLIFIER GAIN RANGE

SWITCH SETTING	NORMALIZED GAIN	GAIN FACTOR
1	1	1
2	2	2
3	4.17	2.09
4	8.33	2
5	16.66	2
6	33.33	2
7	66.67	2
8	133.33	2
9	266.67	2
0	533.33	2

The sensor response time is slowest when the gain setting is the highest. It is recommended that the sensor gain setting should be kept below setting 8 to keep reasonable response time. If additional gain is needed then the gain setting on the front panel of the control unit should be used.

OUT OF TOLERANCE INDICATOR (Fig. 3.4 - 3.8)

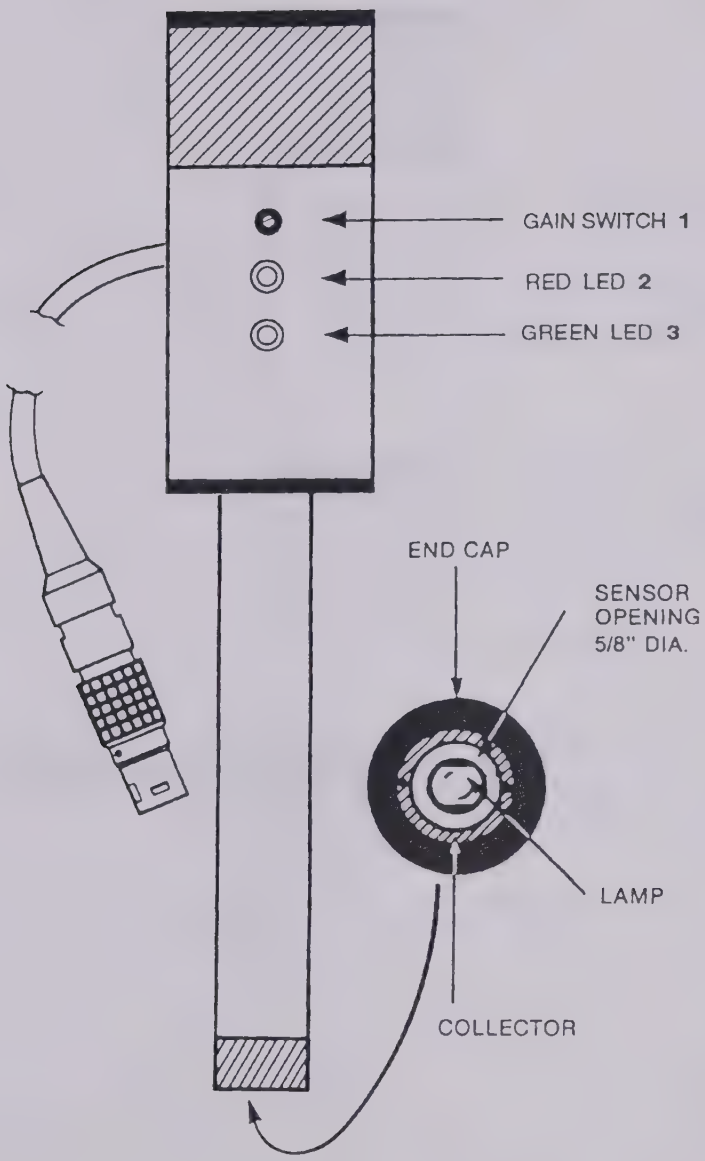
This red lamp will light if the sensor signal is below the "low" window setting or above the "high" window setting. This lamp thus indicates that the signal is outside the acceptance window settings.

IN TOLERANCE INDICATOR (Fig. 3.4 - 3.8)

This green lamp will light if the sensor signal is above the "low" window setting or below the "high" window setting, thus when lit, this lamp indicates that the signal is within the acceptance window setting.

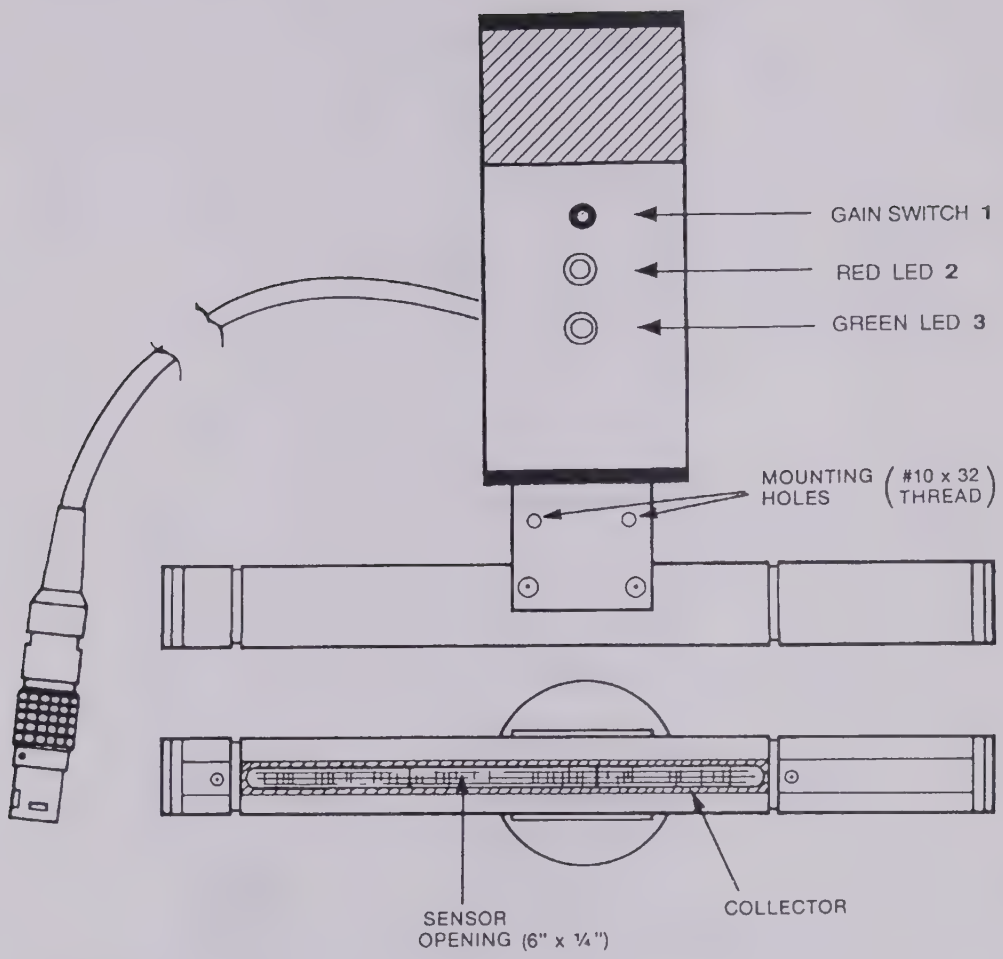
3.5 ADD-ON ACCESSORIES (Fig. 3.9)

A set of apertures (part # 90019) is available for the sensor Model # OPX110 to control the inspected area on the sample. The "OSEE" signal is the average for the UV exposed area beneath the detector. The standard round area sensor detector diameter is 3/8". The aperture set consists of six sizes, .25", .125", and .061", .25" x .0625", .4" x .0625" and .4" x .0313"). These apertures reduce the amount of UV energy reaching the sample surface. The OSEE will also be reduced, in some cases, requiring higher gain settings for the amplifier. It is very important to keep the aperture detector clean. A finger print (or other contamination) on this surface will considerably reduce the detector signal. To clean the aperture detector, remove the aperture and use reagent



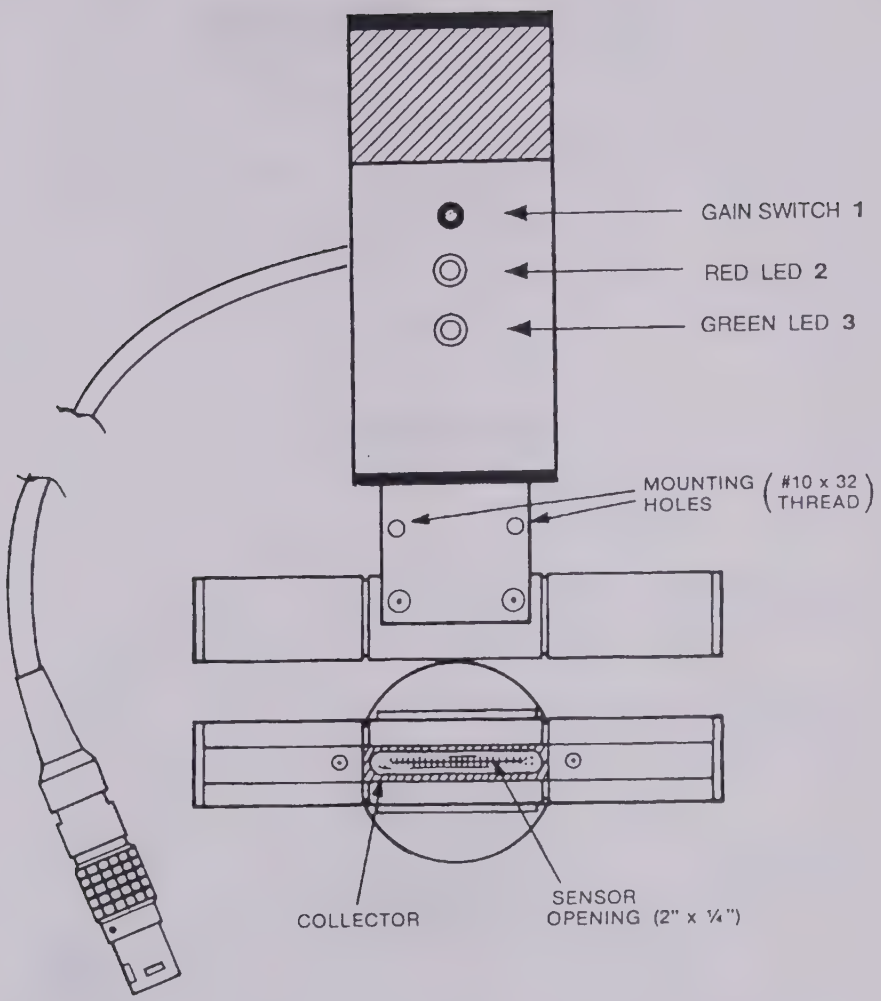
OPX110 - ROUND AREA SENSOR

FIGURE 3.4



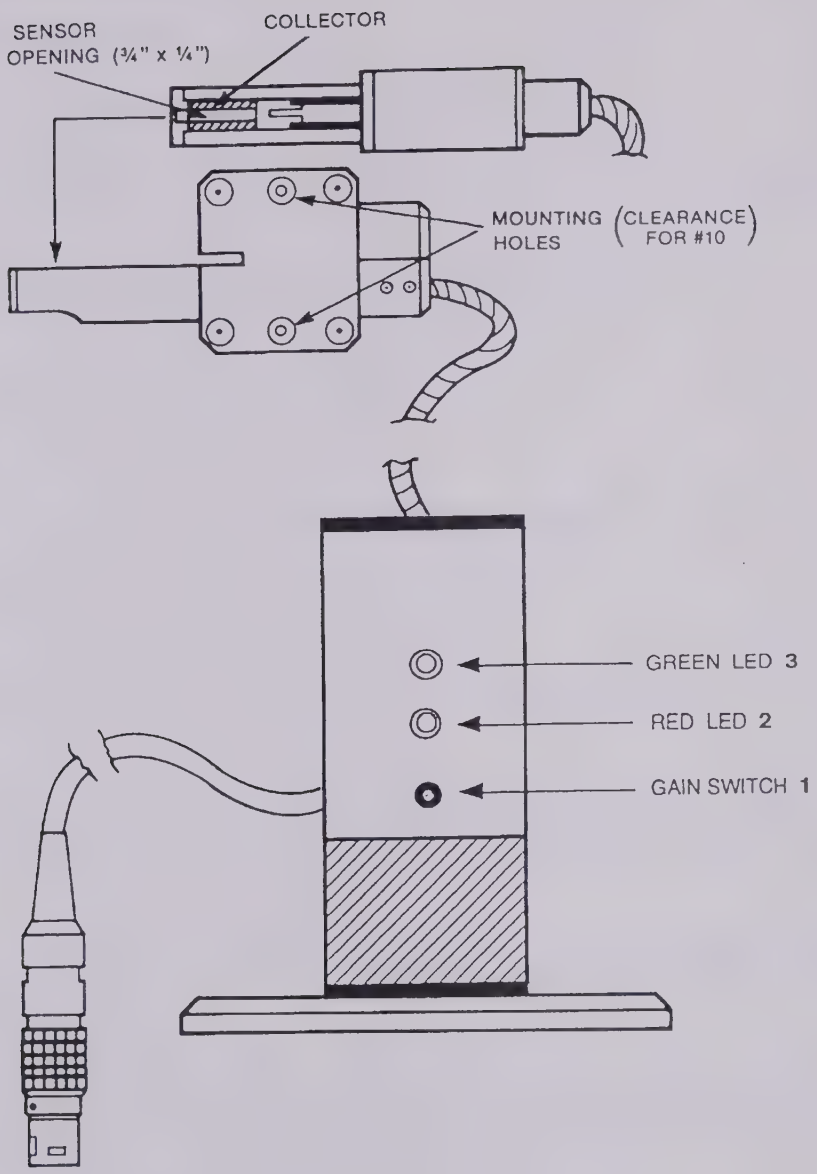
OPX200 - RECTANGULAR SENSOR

FIGURE 3.5



OPX210 - RECTANGULAR SENSOR

FIGURE 3.6



OPX310 - SINGLE DISK SENSOR

FIGURE 3.7

grade acetone or other suitable solvent.

3.6 TURN ON PROCEDURE

To turn on the Model OP1020, proceed as follows:

a) Connect the OP1020 to an AC power outlet using the 3-wire power cord supplied with the instrument.

b) Apply AC voltage to the OP1020 by depressing the power switch; check that the indicator lamp built into the power switch is illuminated.

NOTE: Allow approximately 10 minutes for the UV lamp to warm up and stabilize before taking any readings.

3.7 TESTING INSTRUCTIONS

The control unit can be tested for malfunctions using the built-in Self-Test feature.

3.7.1 CONTROL UNIT TEST

Turn the peak detector off. It is not necessary to connect or disconnect the sensor for the following test:

a) Disconnect the Sample Ground cable from the rear panel. Apply AC power to the control unit. Check and ensure that the power ON indicator is illuminated, the DPM reads 000 and the Sample Ground Warning indicator is flashing.

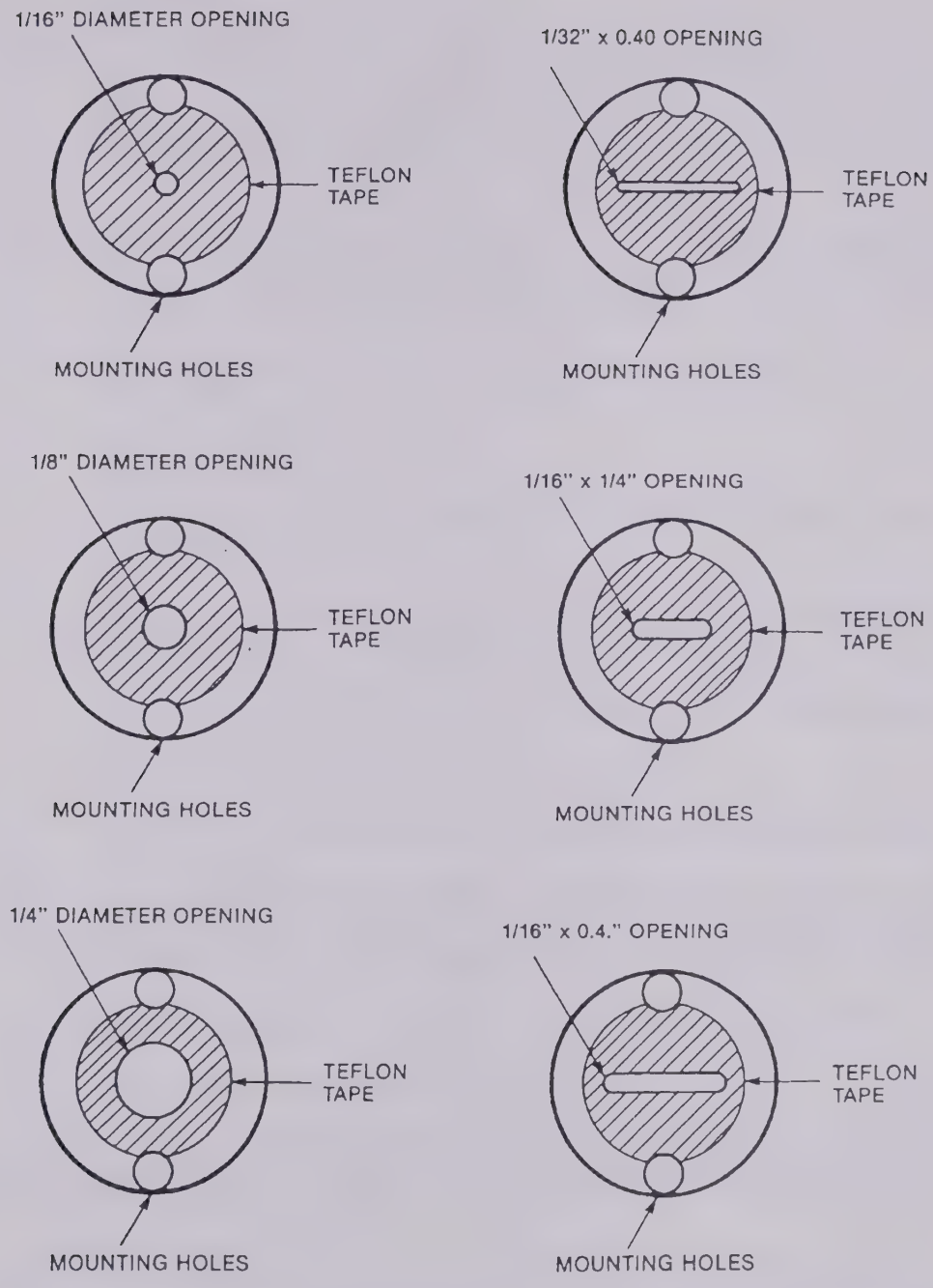
b) Short circuit the Sample Ground connection on the rear panel by using a jumper lead. Check that the Sample Ground Warning indicator on the front panel goes off.

c) Place the Run/Test switch on the rear panel in the TEST position. Rotate the High Gate adjust knob fully clockwise and rotate the Low Gate adjust knob fully counterclockwise. Set the Gain control knob to position 1.

d) Turn the Display Select knob to Low Gate.

e) Turn the Low Gate adjust control clockwise and counterclockwise. Check that the DPM display changes to higher and lower values respectively. The value should range from 0 to 1100. The Accept indicator (green lamp) should be on when the DPM reading is below 500 and the Reject indicator (red lamp) should be on when the DPM reading is above 500.

f) Adjust the DPM reading below 450. Turn the Display select knob to



ASSEMBLY # 90019 - APERTURE SET
(FOR USE WITH OPX110 SENSOR)
FIGURE 3.8

High Gate.

g) Turn the High Gate adjust control clockwise and counterclockwise. Check that the DPM display changes to higher and lower values respectively. The value should range from 0 to 1100. The Accept indicator should be on when the DPM reading is above 500 and the Reject indicator should be on when DPM reading is below 500.

h) Adjust the DPM reading to above 550. Turn the Display Select knob to Signal. Check that the DPM reads approximately 500. Turn the Gain control to position 10. The Over Range indicator should come on.

i) Return the Gain control to position 1. Place the Run/Test switch in the RUN position.

3.7.2 PEAK DETECTOR TEST

a) Turn the control unit power ON and ensure that the Peak Detect switch is OFF (Fig. 3.1, Ref. 5).

b) Turn the Peak Detect switch ON and press the Peak Detect Reset button (Fig. 3.1, Ref. 6). The DPM should read 000.

c) Place the RUN/TEST switch on the rear panel in the TEST position.

d) Observe that DPM reading is approximately 500.

e) Place the RUN/TEST switch on the rear panel in the RUN position.

f) Observe that DPM reading is still approximately 500. NOTE: The value displayed on the DPM will slowly decrease because of capacitor "leakage". However, the DPM reading should be stable for a few seconds.

g) Press the Peak Detect Reset button. The DPM should read 000.

h) Turn the Peak Detect switch OFF.

The control electronics are working satisfactorily if all of the above steps are completed successfully. Please contact your local PAT representative or the factory in case of a problem.

3.7.3 SENSOR TEST

The Sensor functions can be checked by performing the following steps:

a) Ensure that the AC power to the control unit is OFF.

b) Plug the sensor into the sensor connector located on the rear panel. Set

the Sensor Gain control (Fig. 3.3) to position 6. Turn the Control Unit Gain control to position 1 and turn the Peak Detector OFF.

c) Turn the Control Unit ON and check that the UV lamp in the sensor turns on. The lamp will take several minutes to stabilize. (Allow approximately 20-30 minutes for complete warm-up, however the sensor is usable after 3-5 minutes for all but the most exacting measurements).

d) Place the Run/Test switch on the rear panel in the TEST position.

e) Adjust the Low Gate setting below 450 and adjust the High Gate setting above 550. The green lamp on the sensor should be on.

f) Adjust the High Gate setting below 500. The red lamp on the sensor should be on.

g) Place the Run/Test switch on the Rear Panel in the RUN position. Set the Gain control (Fig. 3.3 and 3.4) on the sensor to Position 6.

h) Position the sensor in such a way that the detector cannot "see" a surface. The DPM will display the sensor "back ground" signal. The signal level should be 000. The value may be several counts positive or negative, but this is acceptable. However, if the value is more than 5 to 7 counts positive (no "sign" displayed on the DPM), it may indicate that the detector has become contaminated.

Successful completion of these steps assures satisfactory operation of the sensor.

3.8 OPERATING MODES

The Model OP1020 can be operated in two (2) different modes described below. The selection of the mode depends on the particular application.

3.8.1 PEAK DETECT MODE

This mode is recommended when initially establishing the upper and lower window settings for any application. This mode can also be used for checking of samples with unknown characteristics, however, the accept/reject decision would have to be made by operating personnel by comparing the actual reading with the acceptance window setting.

This mode is selected by placing the Peak Detect switch in the ON position. (Fig. 3.1, Ref. 5).

3.8.2 SCAN MODE

This mode is recommended where either the surface to be inspected is too large to cover with one sensor or the surface or product moves on a production

line.

This mode is selected by ensuring that the Peak Detector is OFF.

SECTION IV:
ADJUSTMENTS MAINTENANCE AND TROUBLESHOOTING

4.1 INTRODUCTION

This section outlines the user performed maintenance and recommended factory maintenance. It also outlines some troubleshooting procedures to trace a problem to the sub- assembly level.

4.2 ADJUSTMENTS

4.2.1 GENERAL

The UV lamp is powered by either: a) high voltage 60HZ transformer, or b) high voltage, high frequency power supply.

The current output on both 60HZ and high frequency power supplies is approximately 18.5 MA. This current cannot be adjusted on 60 HZ transformer. It can, however, be adjusted on the high frequency power supply.

The lamp ages over a period of time, thus its irradiance goes down. In order to compensate for the aging of the lamp, it is recommended that the lamp irradiance be checked monthly. If the lamp irradiance changes significantly (say 5%) then the current on the high frequency power supply should be adjusted.

The procedure for adjusting the current is outlined in section 4.2.4.

4.2.2 EQUIPMENT REQUIRED

Model #	Description	Manufacturer
P6021 (or equivalent)	Current Probe	Tektronix
011-0105-00	Terminator for P6021	Tektronix
8050A (or equivalent)	Voltmeter	Fluke
IL1700	Research Radiometer	Intl. Light
SED240	Detector with Quart window Spectral range 190-320 hm.	Intl. Light
10528	Adaptor for OPX110 sensor	Photo Emission Tech.

4.2.3 IRRADIANCE MEASUREMENT

1. Plug the OSEE Sensor into the OSEE Control Unit. Note: make sure the power to the OSEE Control Unit is OFF before connecting the OSEE Sensor.

2. Turn the power to the OSEE Control Unit ON. Let the lamp warm up for ten (10) minutes.

3. Using the radiometer, detector and adaptor for OPX110 Sensor; take a measurement of irradiance and record this measurement in a log book.

4. Repeat steps 1 through 3 every month and compare the current reading with the initial reading of irradiance. If the reading varies significantly, then the current to the UV lamp should be adjusted.

4.2.4 CURRENT ADJUSTMENT

1. Put the OSEE Control Unit on its side.

2. Remove the four screws holding the bottom cover in place. Remove the bottom cover.

3. Locate the rear of the OSEE Sensor plug on the rear panel. There is a black wire that connects the Sensor connector and high frequency power supply.

4. Connect the current probe to this black high voltage wire and the voltmeter. The probe should connect to the black wire as close to the OSEE sensor plug as possible. NOTE: the arrow on the current probe should be pointing towards the OSEE Sensor plug and not the high frequency power supply.

5. Check and make sure that the switch on the current probe terminator is set at 2 MA/MV.

6. Turn the Unit power ON and check the reading on the voltmeter. The reading should be 9.25 MV. This is equivalent to 18.5 MA as the terminator converts 2 MA into 1 MV.

7. The high frequency power supply is housed in a black anodized enclosure mounted on a vertical plate inside the OSEE Control Unit. NOTE: this enclosure will be visible, when the bottom cover of OSEE Control Unit is removed.

8. The enclosure has a hole in its cover. The trimpot for adjusting the UV lamp current is located directly below this hole.

9. Using a trimpot adjusting tool, turn the trimpot to adjust the current to the UV lamp.

10. Wait for 30 minutes then check the UV irradiance level using the radiometer.

11. Adjust the current to the UV lamp up or down until the desired irradiance level is reached. NOTE: wait 30 minutes after adjusting the lamp current prior to taking irradiance reading.

12. Note and record the current setting and reassemble the bottom cover after removing the current probe.

4.3 MAINTENANCE

a) Inspect the sensor cable and plug before each use for possible wear. If the cable jacket is damaged or worn to the extent that the inner wires are exposed, the cable must be repaired before using the sensor. Check that the strain relief collet in the plug is holding the cable securely. If the cable can be rotated or moved in and out of the plug, the plug assembly must be repaired before using the Sensor. All repairs must be performed by trained personnel.

b) Check and make sure that the pins in the plug on the sensor cable are not bent. If any of the pins are bent, straighten them out using a thin needle nose pliers.

c) As the UV lamp in the sensor ages, the intensity of the UV radiation will decrease. (According to the lamp manufacturer, the average lamp intensity will gradually reduce to the 50% level over a period of 5,000 hours of operation. In addition, each time the lamp is turned from a "cold" start it reduces the lamp life by four hours.) This decrease in lamp intensity will usually result in a decrease of the sensor signal. Therefore, it is recommended that the sensor performance be monitored. Periodically measure a known surface and keep a log of the results. Ensure that all measurement parameters (i.e. surface condition, sensor gain, sensor to sample distance, etc.) are the same each time the test is performed. It is recommended that the peak detect mode be used to make the measurements. If UV lamp replacement becomes necessary, return the sensor to the factory.

d) Degradation of the sensor performance may also be caused by contamination on the sensor detector. If contamination is suspected, carefully clean the detector surface. Use a "clean" lint free absorbent material as a cleaning pad, saturate it with reagent grade acetone (or other suitable solvent) and gently wipe the detector surface. Shake off the excess liquid and let the detector dry out. (Adhesive is present on the horizontal sensors, be very careful and keep the cleaning pad relatively dry to prevent the solvent from running into the collector area and dissolving the adhesive.) After cleaning, re-check the sensor performance. Note that if the cleaning material is not "clean", it is possible to contaminate the detector while attempting to clean it! Also note that the UV

lamp causes the detector to be "self-cleaning" to a certain extent. The UV radiation and the small amount of ozone present tend to react with organic material on the detector and remove it. Therefore, if the detector becomes contaminated it may self clean if the UV lamp is left on for several hours.

4.4 TROUBLESHOOTING

If the system malfunctions, it is usually possible to identify the system sub-assembly that is causing the problem by noting the following general information.

Problems, such as inactive indicators or no sensor signal, are likely to be associated with the Control Board. Replace the Control Board with the one known to be functioning properly and re-check. If this does not solve the problem, it may be necessary to return the instrument to the factory for repair.

If there is no sensor signal, the problem can be isolated by ensuring that the Control Unit passes the test in section 3.7.1 (pp. 20), especially paragraph h. If the Control Unit is functioning as expected, then the Sensor may be malfunctioning. If the Sensor is malfunctioning, especially a burned out UV lamp, it will require factory attention. However, note the maintenance section for possible remedies that may be accomplished by the user.

The Sample Ground circuitry is contained on the mother board. Replacing the mother board should solve any problems with the Sample Ground.

The Peak Detector circuitry is contained on the Front Panel. Replacing the Front Panel with one known to be functioning properly should solve any problem with the Peak Detector.

AN OVERVIEW

OF

O.S.E.E.

APPENDIX TO THE SQM SERIES MANUALS

PHOTO EMISSION TECH., INC.
766 Lakefield Road, Suite H
Westlake Village, CA 91361

March 22, 1991

TABLE OF CONTENTS

1.0 INTRODUCTION 1

2.0 OSEE PRINCIPLE 1
2.1 RESOLUTION 3
2.2 REPEATABILITY AND REPRODUCIBILITY 3
2.4 FACTORS EFFECTING OSEE 5
2.4.1 SHORT-TERM FACTORS 7
2.4.2 LONG-TERM FACTORS 15

3.0 PHOTOEMITTING MATERIALS 16
3.1 SUBSTRATE EMITTING AND CONTAMINANT NON-EMITTING 17
3.2 SUBSTRATE NON-EMITTING AND CONTAMINANT EMITTING 19
3.3 SUBSTRATE AND CONTAMINANT EMITTING 19
3.4 SUBSTRATE AND CONTAMINANT NON-EMITTING 19

4.0 APPLICATIONS OF OSEE 19
4.1 SURFACE CLEANLINESS MONITORING 22
4.1.1 ESTABLISHING SURFACE CLEANLINESS LEVEL 22
4.1.2 SAMPLE APPLICATIONS 23
4.2 DETECTING ABSENCE/PRESENCE OF FILMS/COATINGS 24
4.2.1 ESTABLISHING ACCEPTANCE CRITERIA 25
4.2.2 SAMPLE APPLICATIONS 25
4.3 MEASURING THICKNESS OF THIN FILMS/COATINGS 26
4.3.1 ESTABLISHING OSEE VS. THICKNESS RELATIONSHIP 26
4.3.2 SAMPLE APPLICATIONS 27

1.0 INTRODUCTION

The assurance of a quality surface finish requires that the surface is "properly" prepared. The preparation may involve absence of contamination and/or presence of certain type and thickness of a coating (pre-treatment). Contamination can be defined as any unwanted or foreign material on a surface. Various methods are used to remove a contaminant and condition surfaces to successfully receive coatings, welds, adhesive bonds and decorative finishes.

Contamination can result from inadequate or incomplete cleaning, oxide growth during the time between cleaning and coating, failure to properly protect cleaned surfaces from oils, greases, fingerprints, release agents or deposition of airborne molecular contaminants generated by adjacent manufacturing or processing operations. These films may or may not be uniformly deposited on a large area. This can lead to variations in surface cleanliness. Often these contaminants are invisible, making detection and quantitative measurement difficult. In order to minimize or eliminate surface contamination as a threat to the quality of surface finish, contamination control of surfaces is required.

Thus, in order to eliminate or minimize variations in surface preparation as a threat to the product integrity, strict control of surfaces is required. To assure the proper degree of control, required surface preparation levels must first be established. Second, a method must be established for the uniform preparation of the surfaces to the established levels. Third, a quick, non-destructive method is needed that is capable of monitoring the parts after surface preparation. This assures that the established level of surface preparation has been met and that the process is in control.

Optically Stimulated Electron Emission (OSEE) (first discovered by Dr. Einstein) offers a low cost solution for monitoring in-process surface preparation on a variety of materials. The technique can be used to scan small as well as large areas at speeds up to 7500 ft./min.

2.0 OSEE PRINCIPLE

The SQM series instruments are based on the principle known as Optically Stimulated Electron Emission (OSEE), also known as Photo Electron Emission (PEE). It is a well known fact that when metals or certain other surfaces are illuminated with ultraviolet (UV) light with the proper wavelength (energy), electrons are emitted from the surface. The process by which UV photons interact with the surface to produce electrons is known as OSEE. The emitted and subsequently scattered electrons can be collected across an air gap by a biased collector (located at the end of the sensor) and measured as a current which then is converted into a voltage and displayed on a Digital Panel Meter (DPM) on the SQM series console. By maintaining the surface to collector distance relatively constant, changes in the measured photo current (which is in the order of 10^{-10}

to 10^{-12} amps) can provide information about the surface, e.g., electronic structure, composition chemistry. Any contaminant or thin film on the surface, depending on its own photoemission characteristics, can either enhance or attenuate the inherent emission from the clean surface. In simple electronic terms, the clean surface is a current generator and a non-photoemitting contaminant acts as a resistance because the current is attenuated by interactions between the electrons and the contaminants. The thicker the contaminant, the higher the resistance and consequently the greater the decrease in measured signal.

The sensor utilizes a low pressure mercury vapor lamp with two pre-dominant peaks at 185 nanometers (nm) and 254 nm. These two wavelengths correspond to approximately 6.7 electron volts (ev) and 5.0 ev energy level. The UV light flux provides the energy needed by the material so the electrons emit (escape) from the surface.

The materials/surfaces that emit, when exposed to this UV light, are called photoemitting materials and the other materials are called non-photoemitting. Both substrate and contaminant/coating can be emitting.

A surface with no contaminant or coating on it usually gives a high signal. A contaminant or thin film, depending on its own emission characteristics, can either attenuate or enhance the signal from a clean substrate.

Presence of thin film, contaminant or coating has two effects. First, it reduces the UV light reaching the substrate and second it attenuates the flow of electrons away from the surface. Within a certain range, the signal attenuation is exponentially proportional to thickness of the thin film on the surface. Hence, the OSEE technique can also be used to measure thickness of thin films. The range of thickness measurement depends on the emission level of the substrate and the attenuation level of the contaminant/coating.

This mathematical relationship can be simplified and expressed as follows:

$$I_p = I_o \exp(-d/L) \qquad (1)$$

where I_p is the OSEE signal with attenuating film of thickness, d present. I_o, a constant, is the OSEE signal at $d = 0$, that depends on the work function of the substrate. L, a constant, is the attenuation index representing the resistance to the electron/UV transport through the film.

Equation (1) can be simplified into,

$$d = LN(I_o).L - LN(I_p).L \qquad (2)$$

2.1 RESOLUTION

OSEE is extremely sensitive to very low level changes in surface chemistry. The technique is capable of detecting presence of a partial monolayer of thin film contamination. The range of detection varies from substrate to substrate and has been found to be from a few angstroms up to 750 nanometers.

Spatial resolution is approximately 10% of the area of the sensor opening. For example, if the sensor opening area is 1 square inch, the sensor should be able to detect 0.1 square inch of contaminated area within the 1 square inch area under the sensor opening. The actual spatial resolution will depend on the substrate, the sensor opening and the thickness of contaminant on the surface.

OSEE is not capable of detecting or resolving particulate contamination, but is very sensitive to thin film molecular contamination.

2.2 REPEATABILITY AND REPRODUCIBILITY

Figure 1 shows some typical graphs of OSEE versus time when a surface is exposed to UV light in air. The time and OSEE amplitude scale are usually different for different materials, but the shape of the curve is typical. The following discussion is therefore relevant to OSEE of any material.

When a surface is exposed to UV light, the OSEE signal increases very quickly to a peak signal, then the signal starts decreasing until it stabilizes. The solid line shows the signal when a surface is first exposed to UV light. The dotted line shows the signal when the same spot, on the same material, is exposed to UV light the second time. As we can note, the second curve has a lower OSEE peak than the first curve. This phenomenon occurs due to a very complex process. An oversimplified explanation is that there is a charge that builds up on the surface. This charge will slowly dissipate after the sensor is removed away from the surface. This dissipation time varies with materials, ranging anywhere from a few minutes to many hours.

The conventional approach of repeated measurements on the same spot to show repeatability and reproducibility is not appropriate for OSEE. If a sample is scanned with consistent speed, then the OSEE repeatability and reproducibility can be demonstrated.

Effect of Argon in Airgap

Some recent experiments indicate that the decay phenomenon can be circumvented by introducing a small flow of argon gas in the airgap between the sensor and the sample surface. Replacement of oxygen by Argon reduces the ozone, thus Argon

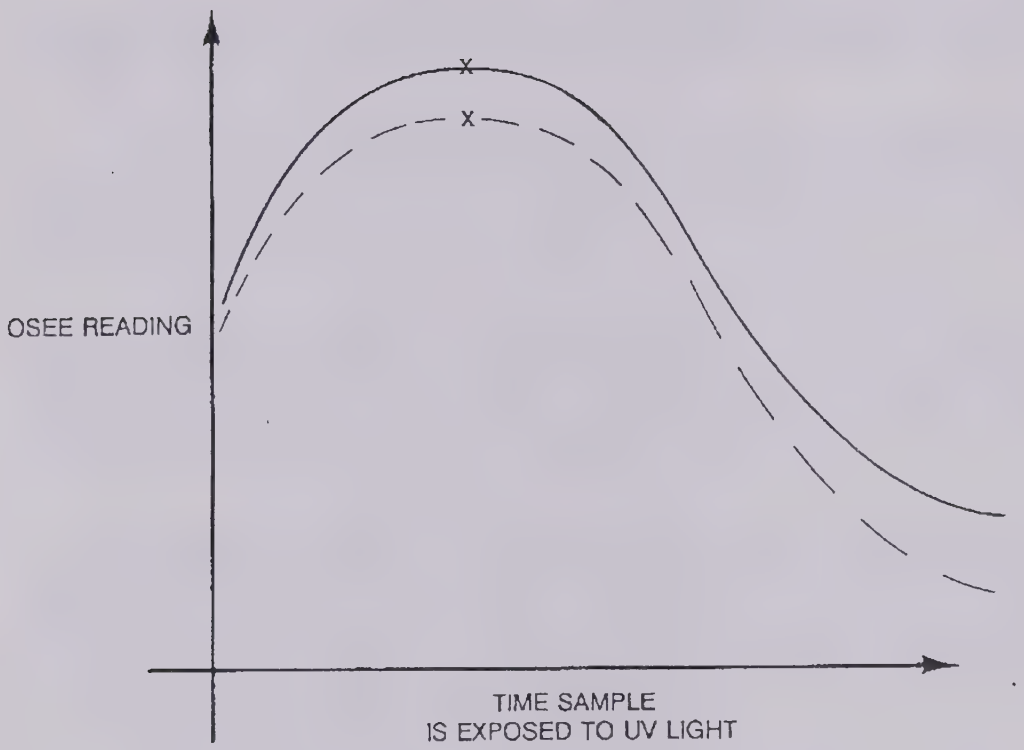


Figure 1

helps in maintaining the OSEE signal at a constant level as indicated in Figure 2. This is accomplished by directing the argon flow relative to sensor geometry. A beneficial by-product of using argon is an increase of the detected surface signal. This is due to the increase in electron transport across the gap in the presence of Argon, vs. air.

2.3 CALIBRATION

Defining the level of cleanliness of any surface, until now, has been very subjective at best. OSEE gives the capability, for the first time, of being able to quantify surface cleanliness level.

Since the idea of quantifying the surface cleanliness is relatively new, there is no national standard on surface cleanliness. The two factors that effect the calibration of the system over a period of time are: changes in the electronics, if any, and the natural aging of the UV lamp.

Several direct calibration methods have been tried with limited success due to the difficulty of being able to maintain a clean surface. Calibration surfaces that have been tried are Gold foil, chemically vapor deposited Gold on glass, chemically vapor deposited Chrome on glass, Stainless Steel and Chrome plated Steel. Of these , Stainless Steel was the most stable and reproducible.

The indirect method involves two steps. One step is to monitor the intensity of UV light from the lamp and making adjustments (available only on models with optional High Voltage, High Frequency power supply) to keep the UV intensity constant over time. If no adjustment is available then the readings should be adjusted to compensate for the percentage loss in UV lamp intensity. The intensity should be monitored using a research type radiometer.

The second step involves checking the electronics using a calibration load (available from Photo Emission Tech.) and making necessary equipment adjustments. If no adjustments are available, then the readings should be adjusted to compensate for the percentage loss in the electronics calibration. Please refer to your system Operator's Manual for further details.

A calibration interval of six months (three months for exacting applications) is recommended. Photo Emission also provides the calibration service.

2.4 FACTORS EFFECTING OSEE

There are a number of factors that effect the OSEE. These factors can be categorized into short-term and long-term factors.

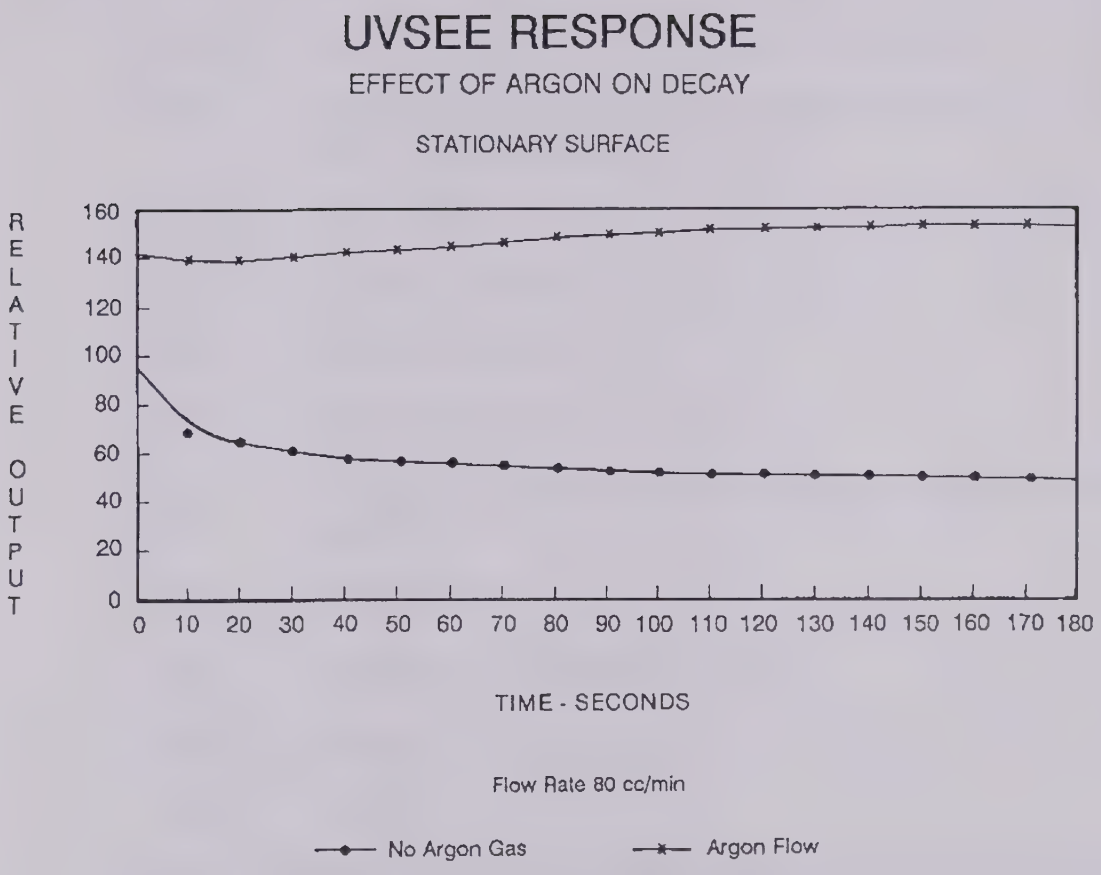

UVSEE RESPONSE
EFFECT OF ARGON ON DECAY
STATIONARY SURFACE
RELATIVE OUTPUT
160
140
120
100
80
60
40
20
0
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180
TIME - SECONDS
Flow Rate 80 cc/min
No Argon Gas
Argon Flow

Figure 2

The short-term factors can be controlled relatively easily. The long-term factors can be monitored and corrected through calibration and/or replacement of component parts in the sensor. Each factor will be discussed along with its effect on OSEE and the type of action needed to control and/or correct the situation.

2.4.1 SHORT-TERM FACTORS:

2.4.1.1 Length of time the surface is exposed to UV light

2.4.1.2 Distance of the sensor from the surface (recommend $^1/_4$" or closer if possible, from the surface)

2.4.1.3 Line voltage

2.4.1.4 Ambient temperature

2.4.1.5 Atmospheric pressure

2.4.1.6 Specimen not properly grounded

2.4.1.7 Coating/contamination too thick (normal range: 2 to 7500 angstroms)

2.4.1.8 Surface finish

2.4.1.9 Air flow/turbulence past the sensor

2.4.1.10 Humidity

2.4.1.11 Static charge

2.4.1.1 LENGTH OF TIME THE SURFACE IS EXPOSED TO UV LIGHT

The shape of the curve in Figure 1 is a typical shape for all materials. The scale for both axis may vary with different materials.
The solid line represents the typical curve when the surface is exposed to UV light for the first time. The dotted line represents a typical curve when the same spot on the same surface is exposed to UV light for the second time. The points marked with an "X" are referred to as the peak readings. Each successive exposure of the surface to UV light during a short period of time (varies with material) will usually result in a lower peak reading.

All materials exposed to UV light eventually recover, i.e. the original

reading can be repeated. The recovery time varies from material to material. It can be a few minutes (e.g. steel) or a few hours (e.g. silicon wafers). No formal data is available on the recovery times for various materials.

It should be noted that due to this unusual phenomenon of the technique, conventional approaches to repeatability and reproducibility are not appropriate. See "Repeatability and Reproducibility" section for more information.

2.4.1.2 DISTANCE OF THE SENSOR FROM THE SURFACE

Figure 3 shows the effect of the sensor distance from the surface on the OSEE readings. The closer the sensor is to the surface being inspected, the OSEE signal. This change in OSEE signal is due to three factors. first, the emitted electrons have more distance to travel. Second, due to the collector being further away from the surface, there is lower electric field. Third, the light flux decreases because of divergence of light.

Once a desirable sensor distance is established, it should be maintained within $\pm$ 0.005".

2.4.1.3 LINE VOLTAGE

Figure 4 shows the effect of variation in line voltage, normalized for 110v, on the OSEE readings. This curve is typical for all SQM series systems that have a high voltage transformer to power the UV lamp. In most applications, the line voltage is not a major problem. Line voltage may become a problem only in applications where very precise measurements are required, such as lubricant thickness within a few angstroms.

In those situations, where it becomes a problem, there are two possible solutions. One solution is to install a line voltage regulator. Photo EMISSION sells a regulator with $\pm$ 0.1% regulation. The other solution is to buy SQM series equipment with a high frequency power supply. The high frequency power supply maintains a constant current to the lamp with a line voltage variation of $\pm$ 15%.

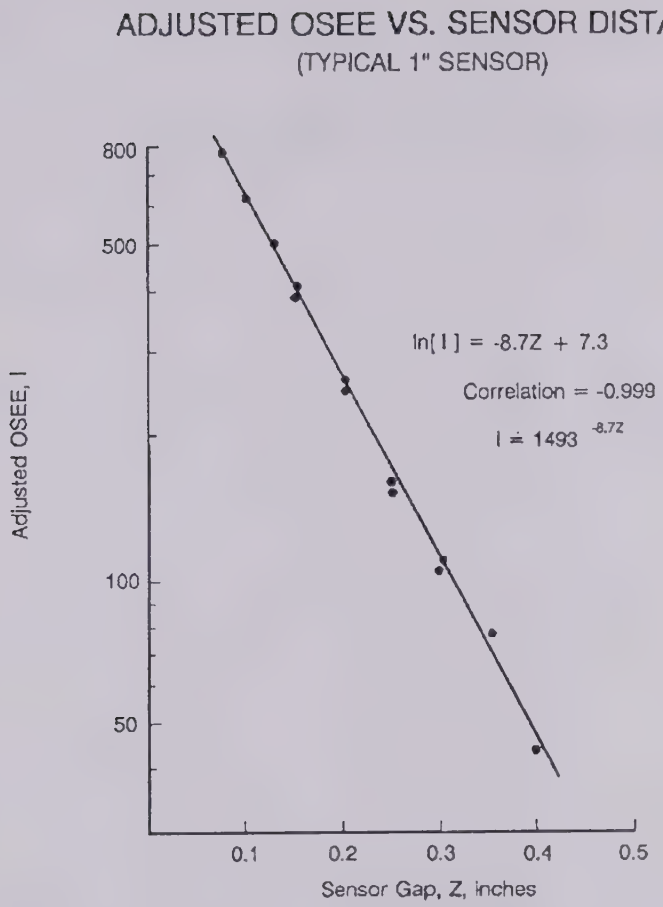

ADJUSTED OSEE VS. SENSOR DISTANCE
(TYPICAL 1" SENSOR)
800
500
100
50
Adjusted OSEE, I
ln[I] = -8.7Z + 7.3
Correlation = -0.999
I = 1493 -8.7Z
0.1
0.2
0.3
0.4
0.5
Sensor Gap, Z, inches

Figure 3

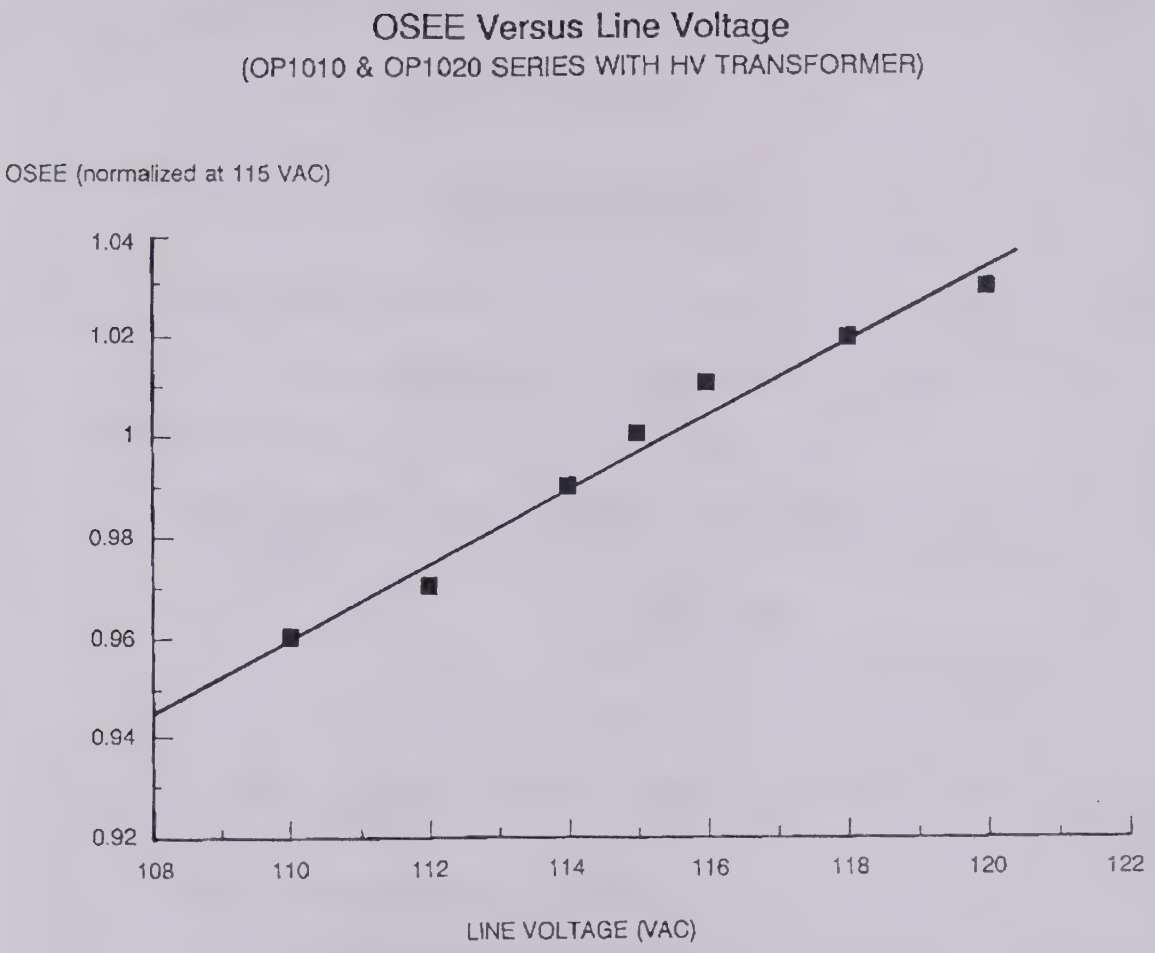

OSEE Versus Line Voltage
(OP1010 & OP1020 SERIES WITH HV TRANSFORMER)
OSEE (normalized at 115 VAC)
1.04
1.02
1
0.98
0.96
0.94
0.92
108
110
112
114
116
118
120
122
LINE VOLTAGE (VAC)

Figure 4

2.4.1.4 AMBIENT TEMPERATURE

OSEE readings increase as the temperature increases. However, the percentage change in OSEE readings is much smaller than the percentage change in temperature. The following is the theoretical relationship between OSEE and temperature.

$$OSEE = F(KT)$$

where K is a constant
T is absolute temperature in Kelvin
$T = 273 + t$ where t is ambient temperature

If t1 = initial temperature = 25° C and t2 = new temperature = 30° C

$$\text{then \% change in temperature} = \frac{30-25}{25} \times 100 = 20\%$$

CHANGE IN OSEE

$$\frac{OSEE2 - OSEE1}{OSEE1} \times 100 = \frac{K(273 + 30) - K(273 + 25)}{K(273 + 25)} \times 100$$

$$= \frac{303 - 298}{298} \times 100$$

$$= 1.7\%$$

For 20% change in ambient temperature (degrees centigrade) OSEE change is expected to be less than 2%.

2.4.1.5 ATMOSPHERIC PRESSURE

OSEE reading decreases as the pressure increases. The exact relationship is not known. Some preliminary work has been done at NASA. The results indicate, a very small change in OSEE for normal change in atmospheric pressure during a year.

PRESSURE VS. OSEE

$$OSEE = F\left(\frac{K}{P}\right)$$

where K is a constant and P is absolute pressure = 760 Torr

As P decreases, V_D increases where V_D is electron drift velocity. As V_D increases, OSEE increases

2.4.1.6 SPECIMEN NOT PROPERLY GROUNDED

It is important to always ground the samples even though the sample material may be non-conducting. The OSEE current is extremely low and leaks easily unless the sample is properly grounded. The sample can be grounded by either attaching the alligator clips, of the ground cable, directly to the sample or attaching the alligator clips to a metal (conducting) plate, and then placing the sample on the grounded plate.

The reason for two alligator clips is to ensure that the work surface (plate) being used is actually conductive. In the case of some materials that are prone to static charge build-up, grounding may not be sufficient. See section on "Static" for more information.

2.4.1.7 COATING/CONTAMINATION TOO THICK

The OSEE reading varies inversely proportional to the thickness of the coating/ contamination as in Equations 1 & 2. As the thickness increases, the OSEE reading decreases logrithmically.

Within a certain range (which varies from material to material) the thickness can be measured. A correlation must be established with some other means of measuring thickness to establish the range of OSEE readings that correspond with the desired thickness range.

The range of thickness that can be measured is dependent upon the work function of the base material, i.e. whether it is high emitting or low emitting, and the type of contamination/coating on the surface. See section 4 "Measuring thickness of thin films/coatings" under "Applications of OSEE".

When the coating/contamination thickness is too thick, the OSEE readings generally will not change significantly as the thickness increases further. Table #1 below is a brief list of data established on the range of thicknesses that can be measured.

TABLE #1

SUBSTRATE MATERIAL	COATING/ CONTAMINANT	RANGE (ANGSTROMS)
D6AC Steel	HD-2 Grease	7,500
Computer Hard Disk Ferrous Oxide Coated	Krytox or Fomblin Lubricant	100
Silicon Wafers	Silicon Dioxide	370
Welding Rod	Calcium Content of the Lubricant	800 Approx. (80 mg/ft^2)

The relationship between OSEE and coatings / contamination thickness is discussed in a later section under "Photo-emitting Materials".

2.4.1.8 SURFACE FINISH

The OSEE readings change as the surface finish changes. In general, the rougher the surface is, the lower the OSEE reading is for a given material. However, the change in OSEE readings is negligible for the range of surface finish/ roughness normally encountered in the industry. Hence, for most applications, surface finish does not become an issue. Table #2 lists data showing some finishes and corresponding OSEE readings.

TABLE #2

EFFECT OF SURFACE FINISH ON OSEE SENSOR RESPONSE

SURFACE ROUGHNESS HEIGHT (U-IN)*	RELATIVE SENSOR OUTPUT
8 Ground with periphery of wheel	658
16 Ground with periphery of wheel	700
32 Ground with periphery of wheel	688
2 Lapped	870
4 Lapped	835
8 Lapped	750
63 Milled	800
125 Milled	824
250 Milled	640

TABLE #2 (Cont'd)

EFFECT OF SURFACE FINISH ON OSEE SENSOR RESPONSE

SURFACE ROUGHNESS HEIGHT (U-IN)*	RELATIVE SENSOR OUTPUT
63 Profiled	863
125 Profiled	799
250 Profiled	520

* Measured on a GAR 22 micro finish comparator

Source: "A Non-contacting Scanning Photoelectron Emission Technique for Bonding Surface Cleanliness Inspection", by Dr. Raymond L. Gause, Marshall Space Flight Center, Alabama. Presented at Fifth NASA Nondestructive Evaluation Workshop, Kennedy Space Center, Cocoa Beach, Florida on December 1-3, 1987.

2.4.1.9 AIR FLOW / TURBULENCE PAST THE SENSOR

In general, OSEE is higher and more stable when the air is still. The higher the flow of air between the sensor and the sample, the lower the OSEE readings.

If the airflow is constant, i.e. not varying or turbulent, then the OSEE is constant assuming everything else is constant. If the equipment is used in an area where airflow is turbulent or varies, it will effect the OSEE readings. In situations where this may be a problem, it can be overcome by placing a shield around the sensor, or relocating the system to another area.

2.4.1.10 HUMIDITY

The OSEE readings are effected by humidity. The readings increase as the humidity increases. Data to determine how much effect the humidity has on OSEE is expected to be developed in the near future. It should be noted that actual effect of humidity has not been a problem in over 200 systems currently in use in the field.

2.4.1.11 STATIC

Static charge build-up on surfaces, particularly non-metallic non-conducting, has an effect on the OSEE readings. The readings are erratic. These erratic readings can occur even though conventional static charge meters may not detect any significant charge.

A quick and convenient way to determine if static is a problem is to use the following procedure.

A) Set up the system to commence testing of samples in question.

B) Turn the peak detect on.

C) Place the sensor directly on the surface of the sample. Note: make sure that the sample is placed on a grounded surface.

D) Let the peak detect capture the peak reading on the digital panel meter.

E) While observing the digital panel meter, quickly remove the sensor away from the surface.

F) If the peak reading on the digital panel meter increases, then static charge is a problem.

G) In the event static charge is a problem, we recommend the use of a static eliminating bar available through most dealers of static prevention equipment. Call Photo Emission if there are any questions.

The materials known to pose a static charge problem are some plastics, glass, malar and polyester.

2.4.2 LONG-TERM FACTORS:

2.4.2.1 UV LIGHT INTENSITY

The intensity of the UV lamp degrades with age and usage. The manufacturer specifies a half-life of 5,000 hours. This means that the intensity of the lamp will reduce to 50% of its initial intensity after 5,000 hours of use. As the lamp intensity degrades, the OSEE readings will drop, assuming all other factors remain constant.

The manufacturer also specifies a four (4) hour loss in life for each cold start of the lamp. Hence, if the lamp is turned off for less than four hours between use, then it is better to leave the lamp on. To assure consistent operation, the system should be calibrated periodically. See "Calibration" section.

2.4.2.2 COLLECTOR BIAS VOLTAGE

Each sensor head has some batteries that are used to bias the collector. This voltage is fixed. The batteries have very little drain on them, hence the useful life of the batteries is the same as its shelf life. Typically batteries last 3-4 years. The batteries do not deteriorate, hence their efficiency is not effected. Batteries keep functioning with the same efficiency throughout their life. They stop functioning suddenly at the end of their life. An easy way of testing the batteries is to touch the sensor collector with a finger. The reading on the digital panel meter should go to approximately 1300. If there is no change in reading, then the batteries are depleted and need to be replaced.

3.0 PHOTOEMITTING MATERIALS

The materials that emit are those which have a work-function of 6.7ev or less. The lower the work-function of a material, the more readily it will emit and the higher the emission level will be. Work-function of a material is a measure of the amount of energy that is needed to release an electron from the surface. Both conducting and non-conducting materials can be photoemitting.

Table 3 gives a partial listing of work-functions of some materials. A more comprehensive list of work-functions may be found in a handbook of physics.

TABLE 3: ELECTRON WORK FUNCTION (EV) OF THE ELEMENTS

MATERIAL	PHOTOELECTRIC WORK FUNCTION (EV)*
Ag	3.67
Al	4.08
As	5.11
Au	4.82
B	4.50
Ba	2.49
Be	3.92
Bi	4.25
C	4.34
Ca	2.76
Cb	3.96
Cd	4.07
Ce	2.84
Co	4.37
Cr	4.37
Cs	1.96

TABLE 3: ELECTRON WORK FUNCTION (EV) OF THE ELEMENTS (Cont'd)

MATERIAL	PHOTOELECTRIC WORK FUNCTION (EV)*
Cu	4.86
Fe	4.40
Ga	3.80
Ge	4.29
Hf	3.53
Hg	4.52
Ir	4.57
K	2.24
La	3.30
Li	2.28
Mg	3.68
Mn	3.76
Mo	4.34
Na	2.28
Nd	3.30
Ni	3.67
Os	4.55
Pb	3.97
Pd	4.97
Pr	2.70
Pt	4.09
Rb	2.09
Re	5.00
Rh	4.57
Ru	4.52
Sb	4.01
Si	4.20
Sm	3.20
Sn	3.62
Sr	2.74
Ta	4.13
Te	4.76
Th	3.57
Ti	4.17
Tl	3.68
U	3.63
V	3.77
W	4.35
Zn	3.89
Zr	3.73

Since both substrates and contaminants/coatings can be emitting or non-emitting, each case will be discussed below.

3.1 SUBSTRATE EMITTING AND CONTAMINANT NON-EMITTING

Figure 5 shows the theoretical relationship between OSEE and contaminant coating thickness for this case.

When the natural log of OSEE is plotted against the thickness of contaminant/coating, the relationship is inverse and linear within a certain range of thickness. Beyond this thickness range, OSEE has maximum sensitivity to detect absence/presence of contamination/ coatings.

3.2 SUBSTRATE NON-EMITTING AND CONTAMINANT EMITTING

Figure 6 shows the theoretical relationship between OSEE and contaminant/coating thickness for this case.

When the natural log of OSEE is plotted against the thickness of contaminant/coating, the relationship is direct and linear within a certain range of thickness. Beyond this thickness range, OSEE has maximum sensitivity to detect absence/presence of contamination/coatings.

3.3 SUBSTRATE AND CONTAMINANT EMITTING

Figure 7 shows the theoretical relationship between OSEE and contaminant/coating thickness for this case.

When substrate is much higher emitting than the contaminant/coating, then the relationship between natural log of OSEE and natural log of thickness is inverse and linear, as shown in the above "Curve A".

When substrate is much lower emitting than the contaminant/coating, then the relationship between natural log of OSEE and natural log of thickness is direct and linear, as shown in the above "Curve B".

3.4 SUBSTRATE AND CONTAMINANT NON-EMITTING

In this case, the OSEE can not be used for any useful purpose.

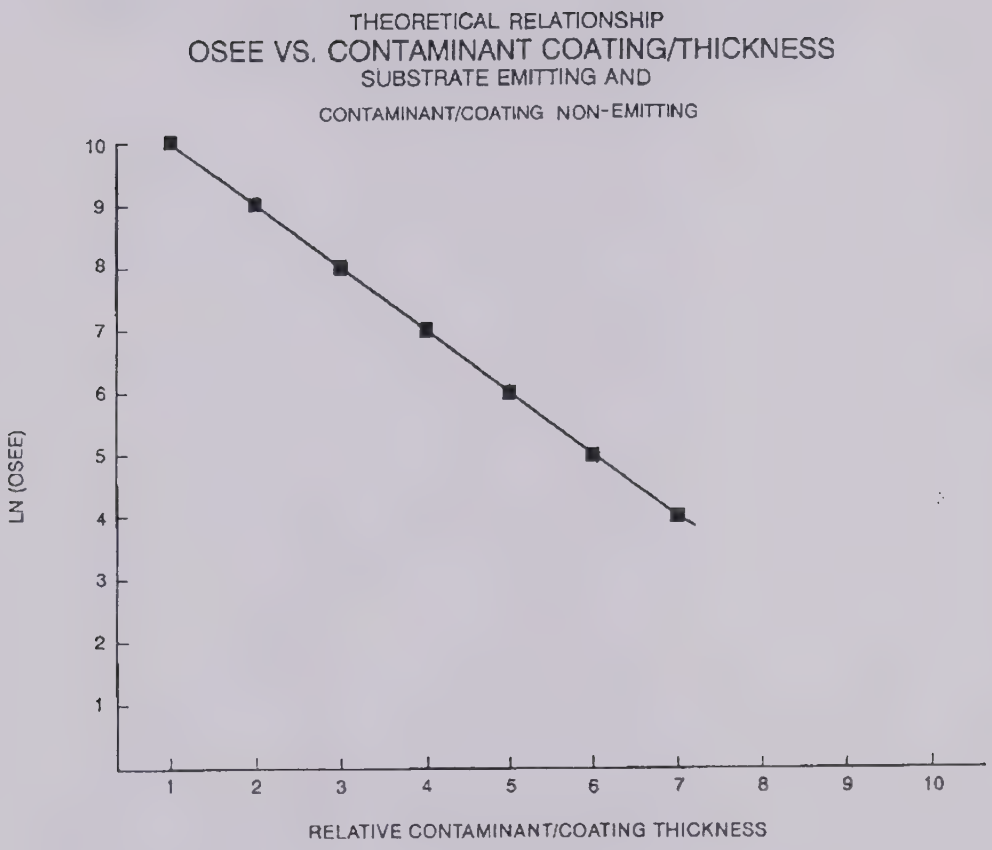


FIGURE 5

Figure 5

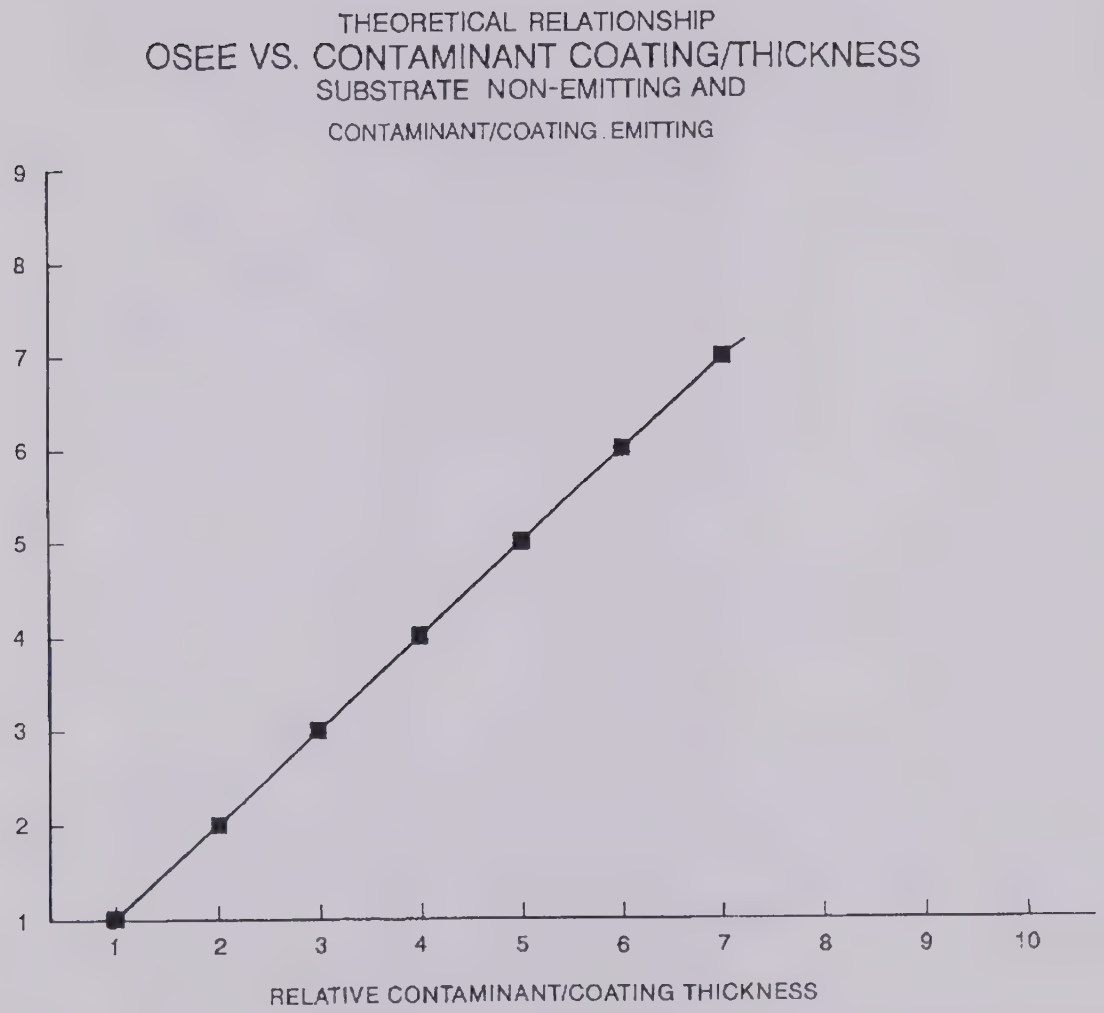

THEORETICAL RELATIONSHIP
OSEE VS. CONTAMINANT COATING/THICKNESS
SUBSTRATE NON-EMITTING AND
CONTAMINANT/COATING EMITTING
9
8
7
6
5
4
3
2
1
1
2
3
4
5
6
7
8
9
10
RELATIVE CONTAMINANT/COATING THICKNESS

Figure 6

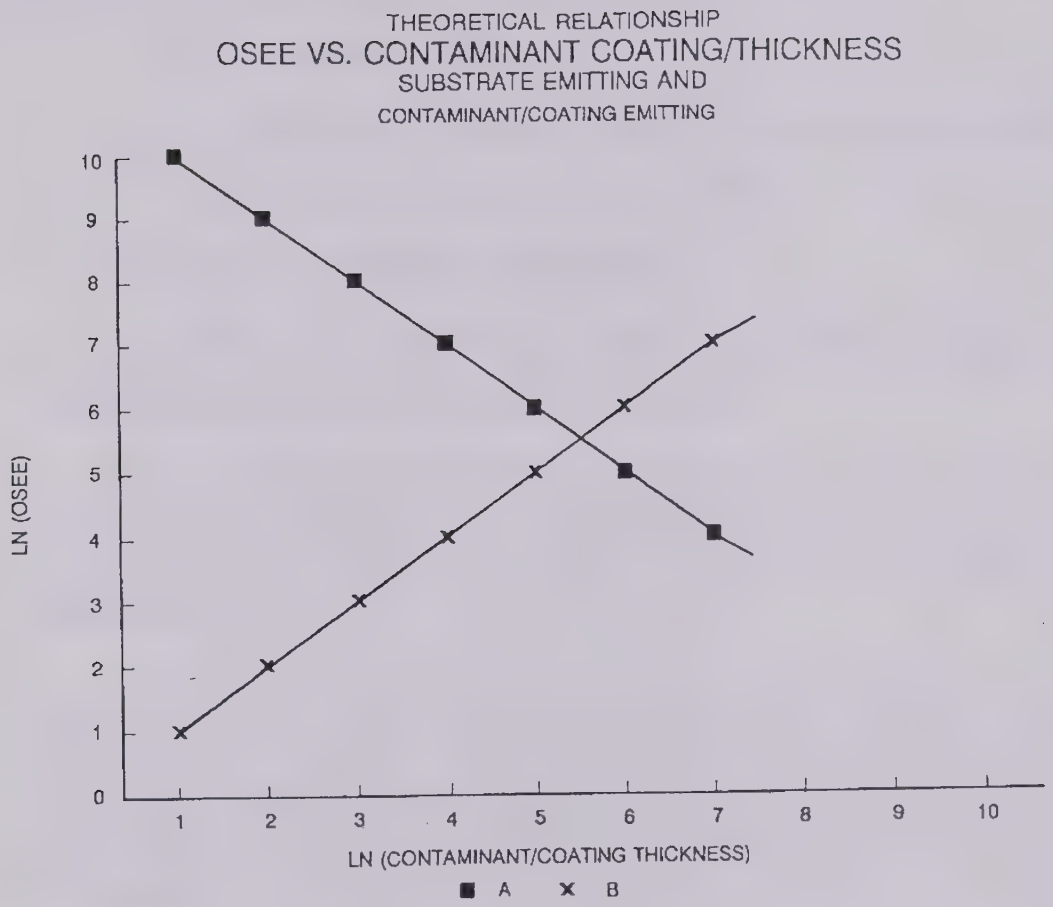

THEORETICAL RELATIONSHIP
OSEE VS. CONTAMINANT COATING/THICKNESS
SUBSTRATE EMITTING AND
CONTAMINANT/COATING EMITTING
LN (OSEE)
0
1
2
3
4
5
6
7
8
9
10
1
2
3
4
5
6
7
8
9
10
LN (CONTAMINANT/COATING THICKNESS)
A
B

Figure 7

4.0 APPLICATIONS OF OSEE

OSEE is extremely sensitive to the changes in the chemical/metallurgical state of a surface. In general, therefore, OSEE can be a very useful technique when changes in the chemical/metallurgical state of a surface need to be detected and monitored.

The following are some specific areas of application for OSEE. Each area of application will be discussed in detail with specific examples.

1) **SURFACE CLEANLINESS**

2) **DETECTING ABSENCE/PRESENCE OF FILMS/COATINGS**

3) **MEASURING THIN FILMS/COATINGS**

4.1 SURFACE CLEANLINESS MONITORING

A quality surface finish requires a surface that is "properly" prepared. The preparation may involve absence of thin film contamination and/or presence of certain type and thickness of a coating (pre-treatment).

Contamination can be defined as any unwanted or foreign material on surface. Defining and maintaining the surface preparation at "proper" levels is, at best, subjective. Often the failure of the surface preparation processes is not discovered until poor quality surface finish occurs, such as poor adhesion of paint/coating, etc.

A lot of empirical work has been done to study and establish suitable surface preparation processes. These processes are controlled by monitoring various characteristics of the process, such as temperature, chemical concentration levels, etc. Despite stringent controls, poor quality product is produced for various reasons. The reasons include, but are not limited to, the number of parts processed between cleaning chemical replenishment and the variation in the amount of contamination on each part.

OSEE is a quick, non-destructive, non-contact method to help establish a quantitative measure of surface cleanliness/preparation. It can be extremely helpful in optimizing surface preparation processes by providing quantitative information about the effect on surface cleanliness/preparation for a given change in the process. The technique can be used very effectively to assure that the process is under control.

4.1.1 ESTABLISHING SURFACE CLEANLINESS LEVEL

The first thing that needs to be established is how large an area should be monitored on a sample. The factors effecting this decision include the spatial resolution required, knowledge of the process and throughput required. In general, the more the spatial resolution, the smaller the area of inspection. Typically, the spatial resolution is 10% of the area inspected. If the sensor opening area is 1 square inch, then contaminated area of 0.1 square inch, within the 1 square inch being inspected, can be detected.

The second thing is to determine whether the test is to be static or dynamic. A static test is where the part is stationary when the test is done. A dynamic test is where the part is moving past the sensor in some material flow process. In a static case, it is recommended that the OSEE sensor be placed on the sample surface and "peak detect" mode on the instrument be used to capture and record the highest reading from the surface. If a non-contact test is desired, then the sensor must be mounted in a stand and the part placed under the sensor. In a dynamic test, the sensor is mounted such that the sensor distance from the sample surface is as small as possible (less than 1/4",typically 1/8") and this distance is maintained.

A few samples that are known to be clean should be tested to select best gain settings on the sensor and front panel. Gain settings should be selected such that the highest possible reading is obtained from these clean samples, but should not be more than 1000. Once the best gain settings are established, these should be recorded.

Next, a statistically significant sample of clean parts should be taken. Each part should be tested and the peak OSEE reading recorded. Once the readings from all the samples have been recorded, the mean and the standard deviation of these readings should be calculated.

It is recommended that $\pm$ 3 standard deviation limits be established as the upper and lower acceptance level for the surface cleanliness. These limits can be set on the OSEE instruments as upper and lower gate settings. Once these settings are established, production parts can be tested. If the cleanliness of the parts is outside the acceptance range, the red light on the sensor and on the front panel of the control unit will come on indicating a reject, otherwise the green light will serve to indicate the part is clean within the specification.

Once this quantitative acceptance criteria has been established, the effect of changes in the process can be assessed by evaluating how these changes effect the surface cleanliness level. In general, the cleaner the

surface, the higher the OSEE reading from that surface.

4.1.2 SAMPLE APPLICATIONS

4.1.2.1 Aerospace Industry

"The performance of many critical components for the Space Shuttle and other flight hardware depends on the quality of bonding achieved during manufacturing. An example of a major shuttle element, where quality bonding is crucial to performance reliability and safety, is the Solid Rocket Motor (SRM). Inadequate bonding of the rubber insulation to the case could result in exposure of the D6AC steel case to the hot gases from the burning propellant and result in a burn-thru which could be disastrous. Thin film surface contamination is probably the most insidious and least understood parameter that effects bonding."

Studies were performed to correlate the relationship between the level of contamination versus the peel strength of the bond. The relationship between the level of contamination versus OSEE signal was also established.

Prior to the use of OSEE, there was no method to detect contamination levels less than 100mg/square foot, which resulted in average bond strength of 59 pounds per linear inch (PLI). The use of OSEE has given NASA the capability of monitoring surface contamination down to 0.25mg/square foot. Better cleaning methods were developed by using OSEE to optimize the cleaning process. As a result, an average bond strength of 196 PLI has been achieved, a three fold increase in bond strength.

4.1.2.2 Surface Finish

In one application, aluminum panels are anodized, silk-screened, sheared and shape formed for control panels and decals for household appliances and automotive trim. The OSEE technique has been used to establish the acceptable level of cleanliness to improve the adhesion of anodizing and silk-screening to the aluminum panel. The effectiveness of the cleaning process is also monitored on-line to assure that the surface cleanliness meets the established standard.

In another application, steel sheet is hot dip galvanized. There was a problem of "bare spots", areas on the steel sheet which had no adhesion of the galvanized coating. This problem was minimized by using OSEE to establish and monitor, on-line, the effectiveness of the cleaning process prior to coating. An additional benefit of the use of this technique was to reduce the chemical concentration of the cleaning bath by 40% and still improve the

coating adhesion.

4.2 DETECTING ABSENCE/PRESENCE OF FILMS/COATINGS

There are several applications where thin films or coatings are applied to a surface to enhance certain product characteristics or aid in further processing of parts. For example, computer hard disks and floppy disks have a very thin film of lubricant applied to enhance the life and performance of the product. In other cases, clear coatings are applied to certain surfaces to protect against corrosion or deterioration of surface finish. In many of these cases, it is important to know if the film or coating is present on the surface or not. OSEE is a quick and non-destructive method for monitoring surfaces for absence/presence of films and/or coatings.

4.2.1 ESTABLISHING ACCEPTANCE CRITERIA

In establishing a test method, the factors concerning the size of the sensor, static or dynamic test and contact/non-contact method need to be established first. (See discussion under "ESTABLISHING SURFACE CLEANLINESS LEVEL" for more information.) Once these factors are established, the optimum gain settings for a given test must be established. To do that, take OSEE readings from some coated and uncoated parts. Adjust the sensor gain setting and front panel gain setting, such that highest possible OSEE readings are obtained from uncoated parts. The readings should not exceed approximately 1100. Generally, uncoated parts give higher OSEE readings, however, in some cases coated parts may give higher OSEE readings. In such case, the gain settings should be established to give highest readings on coated parts.

Next, a statistically large enough sample should be taken of both coated and uncoated parts. OSEE readings should be taken and recorded for each sample in both groups. Mean and standard deviation for both groups should be calculated to establish $\pm$ 3 standard deviation limits for both groups. The upper and lower acceptance limits for coated parts should be entered into the OSEE control units. Once this is done, production parts can be tested to determine absence or presence of coating. A red light on the sensor and the front panel of OSEE control unit will indicate an uncoated part.

The purpose of taking readings on both sets of parts is to establish the usefulness of OSEE for the purpose of detecting absence/presence of coatings. In general, the further apart the readings are for the two sets of samples, the more assurance there is that the OSEE can be very effective in detecting surface films/coatings. For further information or discussion on your

application, please contact the factory.

4.2.2 SAMPLE APPLICATIONS

4.2.2.1 Computer Hard Disk Manufacturing

The computer hard disk has a very thin coating of lubricant applied as a final operation, prior to assembly in the disk drive. The thickness of the lubricant film is very critical to the performance of the disk drive. The lack or absence of lubricant will result in excessive wear of read/write head, thus considerably reducing the useful life of the disk drive. Too much lubricant results in "stiction", where the read/write head sticks to the disk, possibly causing permanent damage.

OSEE is being used by most hard disk manufacturers to monitor for absence/presence of lubricant in production.

4.2.2.2 Aircraft Industry

In the aircraft industry, the fuselage sheets are clear anodized to protect against corrosion. It is important to know that the sheets are anodized all over, i.e. there are no bare spots. In addition, the thickness of anodize coating is also important. OSEE equipment is being used to check bare spots on sheets by an aircraft manufacturer. It is anticipated that after some base data has been gathered, OSEE can be used to monitor variations in anodize coating thickness.

4.3 MEASURING THICKNESS OF THIN FILMS/COATINGS

As discussed earlier, a surface without any contamination or coating usually gives a high signal, which is then attenuated by the contamination or coating. The attenuation of the OSEE signal is inversely proportional to the thickness of contamination or coating within a certain range of the thickness of the contamination or coating. This range varies from material to material and the type of contaminant or coating. Typically this range is approximately 500 angstroms with a maximum of 7500 angstrom range recorded on HD2 grease on D6AC steel.

OSEE is a comparator and it gives readings in OSEE units and not in thickness units, e.g. angstroms. To determine the relationship between OSEE response versus the thickness and the range of thickness within which the relationship is proportional, tests need to be conducted on samples with known but different amount of contamination or coating thickness.

4.3.1 ESTABLISHING OSEE VS. THICKNESS RELATIONSHIP

Once again in establishing a test method, the factors concerning the size of the sensor, static or dynamic test and contact/non-contact method need to be established first. (See discussion under "Establishing Surface Cleanliness Level" for more information.) Once these factors are established, the optimum gain settings for a given test must be established. To do this, readings should be taken from parts with no film/coating. Sensor gain setting should be adjusted to obtain maximum readings but not exceeding approximately 1100.

Next, samples should be prepared/collected to cover the range of thickness encountered during normal measurement, including samples with no films/coatings. It is important to know the film/coating thickness on each sample. These measurements should be established using some other means of measuring thickness.

OSEE measurements should be taken from each sample preferably in the same area where measurements were taken with the other method. This would prevent any errors due to variations in thickness across a sample. OSEE readings should be recorded for each sample. It is recommended that at least five samples of each thickness should be measured and an average of five samples be used in establishing OSEE vs. thickness relationship.

The natural log of OSEE readings should be correlated with thickness readings obtained with the other method. Using linear regression, the best fitting straight line can be found and the slope and intercept of that line can be established. A graph should be prepared to make sure that the relationship is linear over the range of thickness measured. If relationship is not linear over the full range, then the linear regression should be done only on the linear range. The relationship derived will be of the type:

$$Y = C - mx$$

where m is the slope, C is the intercept, Y is the thickness and x is natural log of OSEE. This relationship will also define the range of thickness that can be measured for this particular substrate and the type of film/coating.

4.3.2 SAMPLE APPLICATIONS

4.3.2.1 Computer Hard Disk

To minimize interaction of the read/write head on the magnetic disk

surface, it is common for manufacturers of magnetic media to add an extremely thin layer (5-50 Angstroms) from a series of commercially available fluorocarbon lubricants, to reduce stiction/friction and increase disk life durability under a wide range of conditions (typically 30,000 contact start stop cycles).

The application and control of a known exact thickness of fluorocarbon lubricant is of critical importance in reducing stiction/friction when two other factors are considered in conjunction, namely the type of overcoat (usually carbon) and the surface finish of the disk (average roughness).

Insufficient lubricant or absence of the lubricant will result in excessive wear of read/write heads and "crashes" can occur. Too much lubricant results in "stiction", where the read/write head sticks to the disk, possibly causing permanent damage.

4.3.2.2 Welding Wire

To maintain proper feeding of welding wire through the automatic welding guns, a lubricant with calcium is applied to the welding wire. The level of lubricant thickness must be maintained within certain range. Too much lubricant results in "over feeding" the welding wire which may result in cold/ poor welds. Too little lubricant results in "under feeding" the welding wire, resulting in voids/poor welds.

OSEE is being used to monitor lubricant thickness on-line and provide a real time control of the lubricant application process.

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447-13B	JET BLACK	44754
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447-13E	FOREST GREEN	44757
447-13J	SKY BLUE	44758
447-13M	LIGHT GRAY	44771
447-13LE	MIST GREEN	44791

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